

Deep Geological Repository Conceptual Design Report Crystalline / Sedimentary Rock

APM-REP-00440-0211-R000

September 2021

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Nuclear Waste Management Organization

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Document History

Title:	Deep Geological Repository Conceptual Design Report Crystalline / Sedimentary Rock
Report Number:	APM-REP-00440-0211
Revision:	R000
Nuclear Waste Management Organization	
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Revision Summary		
Revision	Date	Description of Changes / Improvements
R000	2021-09	Initial issue

ABSTRACT

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Crystalline / Sedimentary Rock
Report No.: APM-REP-00440-0211-R000
Author(s): N. Naserifard, A. Lee, K. Birch, A. Chiu and X. Zhang
Company: Nuclear Waste Management Organization
Date: September 2021

Abstract

The Nuclear Waste Management Organization (NWMO) is implementing Adaptive Phased Management (APM), Canada's plan for the long-term management of used nuclear fuel. The APM approach encompasses centralized containment and isolation of the used fuel in a Deep Geological Repository (DGR) in a suitable rock formation, such as a crystalline rock or sedimentary rock geosphere, in an informed and willing host community.

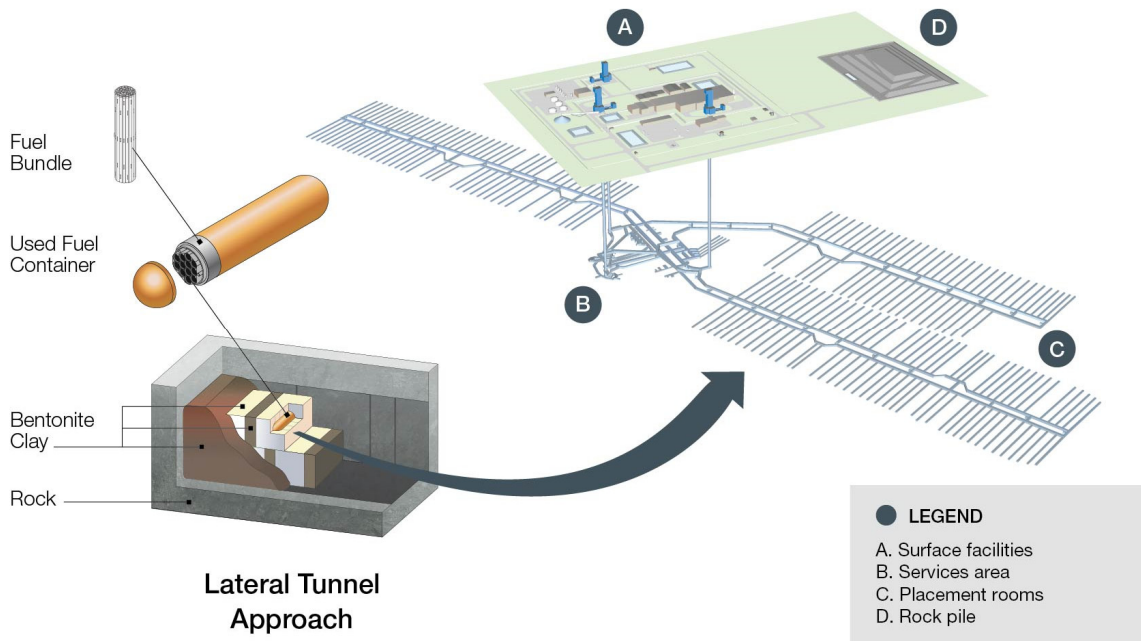
This report describes conceptual designs for a DGR facility in either crystalline or sedimentary rock. For costing purposes, it is assumed that the facility will receive 5.5 million used CANDU fuel bundles over a 46-year period. The report describes the required facilities and infrastructure needed to safely receive, package, and emplace the used nuclear fuel in the underground repository. At the end of emplacement activities and following a period of extended monitoring the DGR facility will be decommissioned and closed. All underground rooms, tunnels and the three shafts will be permanently sealed.

EXECUTIVE SUMMARY

The Nuclear Waste Management Organization (NWMO) is implementing Adaptive Phased Management (APM), Canada's plan for the long-term management of used nuclear fuel. The APM approach encompasses centralized containment and isolation of the used fuel in a Deep Geological Repository (DGR) in a suitable rock geosphere, such as crystalline rock or sedimentary rock within an informed and willing host community.

In January 2020, the NWMO announced that the Ignace area in northwestern Ontario and South Bruce area in southern Ontario will undergo more detailed investigations to determine suitability for hosting the DGR. The Ignace Area has a crystalline rock geosphere while the South Bruce Area has a sedimentary rock geosphere. This report describes DGR facility concepts for these two locations. The concepts will continue to be updated to support future licensing submissions and as new information becomes available from on-going site investigations at these two locations.

As of June 2020, Canada has produced over 3.0 million used fuel bundles. If Canada's existing reactors operate to the end of their planned lives, including planned refurbishments, the inventory that will need to be managed in the DGR facility is estimated to be 5.5 million bundles. An inventory of 5.5 million used fuel bundles is also used in the life cycle cost reporting. The used fuel bundles inventory is reviewed annually by the NWMO.



Deep Geological Repository (DGR)

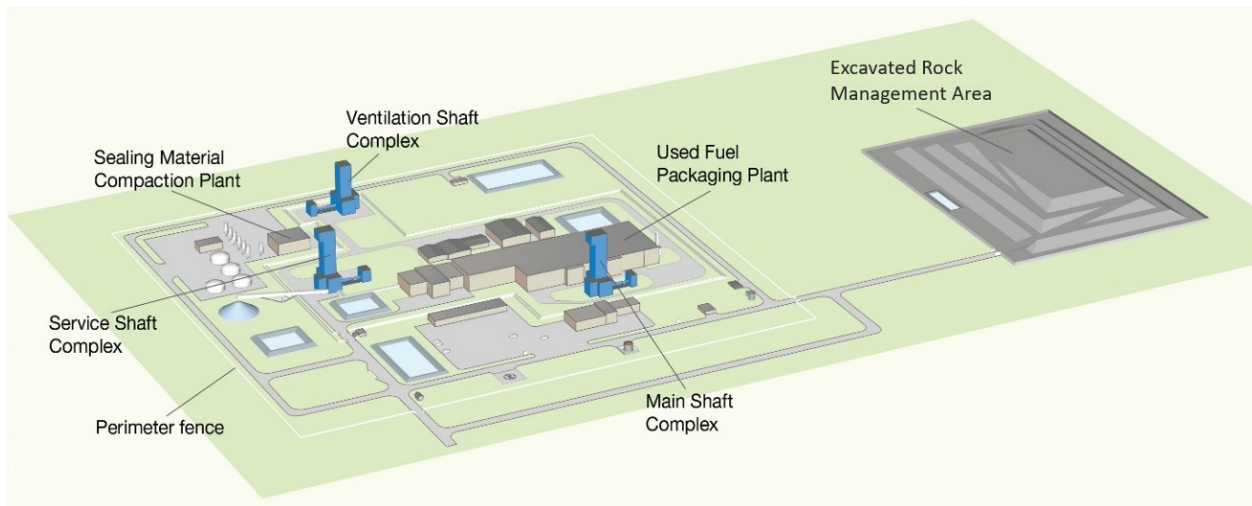
This report describes concepts for a DGR facility in crystalline and sedimentary rock. It describes the required facilities and infrastructure needed to safely receive, repackage, and emplace the used nuclear fuel into the DGR safely using a series of Engineered Barriers including the Used Fuel Container (UFC) and bentonite clay.

Surface Facilities

The DGR facility will be self-contained and will have facilities for operation, maintenance and long-term monitoring.

For security purposes, certain areas of the surface facilities will have restricted access and will be located inside the Protected Area. The Protected Area will include the Used Fuel Packaging Plant, Main Shaft Complex, Service Shaft Complex and Ventilation Shaft Complex. Security and double perimeter fencing will be required to prevent unauthorized access into the Protected Area.

Surface facilities located outside the Protected Area, but inside the outer perimeter fence, are considered the Balance of Site. The Balance of Site area will include the Administration Building, Sealing Material Compaction Plant and a Concrete Batch plant.



Deep Geological Repository (DGR) Main Surface Facilities

External facilities, located outside the DGR's perimeter fences, will be required to support the DGR facility. Such facilities include a Centre of Expertise and accommodation for construction personnel. An Excavated Rock Management Area (ERMA) from the underground repository and the associated stormwater management pond will also be required. The location and footprint will be determined as new information becomes available from on-going site investigations.

Used Fuel Packaging Plant (UFPP)

The used nuclear fuel will be received at the Used Fuel Packaging Plant (UFPP) from the interim storage sites located at the reactor sites. The used fuel will be transported in two certified road transportation packages; the Used Fuel Transport Package (UFTP) and Basket Transportation Packages (BTP). These transportation packages will be received at the UFPP where the contained used fuel bundles will be transferred to the Used Fuel Containers (UFC). The filled UFCs will then be sealed by welding, inspected and assembled into bentonite buffer boxes. The buffer boxes will be made of two blocks of Highly Compacted Bentonite (HCB) clay with a cavity machined in these blocks to hold the UFC. These buffer boxes, each containing a UFC, will then be dispatched for placement in the underground repository.

The UFPP will incorporate multiple processing systems for receiving and unloading used fuel from the transportation packages and for safely processing and handling the UFCs.

Sealing Materials Production Plant

Sealing Materials Compaction Plant (SMCP) and Concrete Batch Plant operations will be required to produce repository sealing materials needed for the underground Engineered Barrier Systems (EBS) (e.g., bentonite blocks, granular bentonite gap fill material, concrete bulkheads, etc.). Imported aggregate will be stockpiled and then used to support the material needs of the SMCP and concrete batch plant.

At the SMCP, Highly Compacted Bentonite (HCB) blocks for the buffer boxes will be manufactured and transferred to the UFPP. The SMCP will also produce HCB spacer blocks and granular bentonite Gap Fill Material (GFM) that will be placed inside each placement room. The plant will employ custom designed presses, moulds and shaping equipment for manufacturing the HCB blocks with specialized lifting devices in place to handle the formed materials. In addition, during decommissioning the SMCP will manufacture dense backfill (DBF), GFM and HCB in support of repository underground closure operations.

At the concrete batch plant, aggregate will be blended with binders and a water reducing admixture to produce Low Heat High Performance (LHHP) concrete. The LHHP concrete will be used for construction of bulkheads at entrances of the UFC-filled placement rooms in the repository underground. These concrete bulkheads will be part of the placement room seal.

Shafts, Headframes and Hoisting Systems

Three shaft complexes (shafts, headframes and hoisting systems) will support the underground repository. The Main Shaft Complex will serve as the exclusive conveyance structure for the surface-to-underground transfer of the buffer boxes (with UFCs). The hoisting system will be tower-mounted concrete headframe structure approximately 60m high. The friction hoisting system will have a payload capacity of about 60 tonnes. The hoisting system will raise/lower a cage inside a 7m inside diameter concrete lined shaft.

The Service Shaft Complex will be a multi-purpose hoisting facility with three hoisting systems for movement of personnel and materials into and out of the repository. The hoisting systems will be tower-mounted inside a concrete headframe structure approximately 50m high. The Service Shaft Complex will incorporate equipment for delivering excavated rock to ground surface (skips), a main service hoist for movement of personnel and materials to the underground repository, and an auxiliary hoist for personnel movement both during normal operations and emergencies. The hoisting systems will raise/lower the skips and the two cages inside a 7m inside diameter concrete lined shaft.

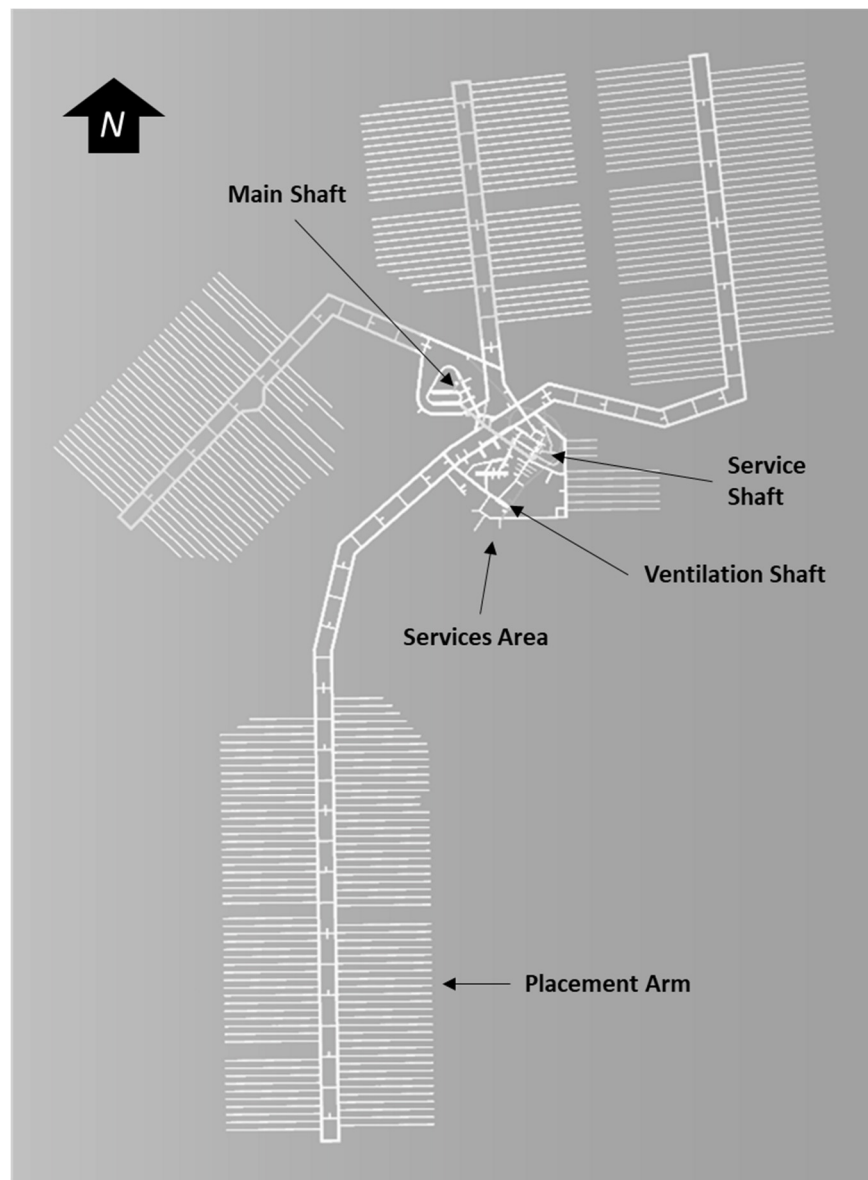
The Ventilation Shaft Complex will handle most of the repository exhaust air and will have an auxiliary hoist to provide a secondary means of egress for personnel in the event of an underground emergency. The hoisting system will be ground-mounted beside a steel headframe structure approximately 30m high. The headframe structure will be located above a 7m inside diameter concrete lined shaft through which ventilation air will be exhausted to surface and the auxiliary cage will operate.

Underground Facilities

The underground facilities will be comprised of the following two main areas: a) Services Area located at the base of the three shafts and b) Panels of rooms located in repository placement arms accessible by parallel access tunnels.

The following figure illustrates the layout of the underground repository (for the crystalline rock design concept).

The underground layout is designed to allow adaptability to site specific conditions. Specifically, the direction and location of the branching placement arms will change as site investigations proceed.



Underground Repository Layout Concept (Crystalline Rock Geosphere)

The Services Area will provide a range of facilities to support DGR operations:

- Underground Demonstration Facility;
- Refuge stations, offices, washrooms;
- Maintenance shop and warehouse;
- Battery charging station;
- Equipment / material storage areas;
- Explosives and detonators magazines;
- Main electrical substation; and
- Truck dump equipped with grizzly and rockbreaker.

The Underground Demonstration Facility (UDF) will be situated near the shafts and established soon after the repository level is reached. The UDF will support geoscientific verification, validation of construction methods, demonstration of excavation and placement techniques and long-term demonstration of the sealing systems. There is also a potential for using the UDF as a training area for future underground activities for DGR personnel.

The in-room placement of the buffer boxes containing the UFCs will involve a two-high stacking arrangement of the boxes. The rows of boxes will be separated by HCB spacer blocks. The buffer boxes will be placed in a retreating arrangement within the placement room with any remaining voids backfilled with granular bentonite Gap Fill Material (GFM).

The basic arrangement of the underground repository involves a series of parallel, dead-end placement rooms, organized into panels. All underground openings will be excavated by controlled drill and blast methods. The placement rooms will have a rectangular shape of nominal dimensions about 3.2 m wide by 2.4 m high.

Heat will be generated by the UFCs. Such heat and the resulting elevated thermal regime will be evaluated with respect to potentially induced thermal stresses, as well as the requirement that temperature on UFC surfaces must be below 100°C at all times. To meet this thermal requirement, the center-to-center spacing of the buffer boxes is set at approximately 1.3 m for crystalline rock and 1.7 m for sedimentary rock. In addition, the center-to-center spacing of placement rooms will be set at 25 m for both crystalline and sedimentary rock geospheres. These values are dependent on the site-specific geosphere; as a result, they will be updated as site investigations proceeds.

During the Construction Phase of the underground repository, the Services Area including the UDF, and all access tunnels that extend into the placement arms will be developed. Following the start of operations, excavation of placement rooms will proceed concurrently with placement activities. There will be separation of development (excavation) and UFC placement activities from a worker, ventilation and equipment perspective.

For both crystalline and sedimentary geospheres, and depending on geologic conditions encountered, the underground repository will likely cover an area of approximately 2 by 3 kilometers (about 1,500 acres or 600 hectares).

Underground Ventilation

Three primary airways will be used to ventilate the repository. The Service Shaft will constitute a dedicated fresh air passage. The primary exhaust air passage will be via the Exhaust Ventilation Shaft and relatively small amounts of air will exhaust via the Main Shaft. A series of surface fans and underground booster fans will be required to achieve the design air flow distribution in the underground repository. A surface-based fresh air heating plant will be used to heat air in winter

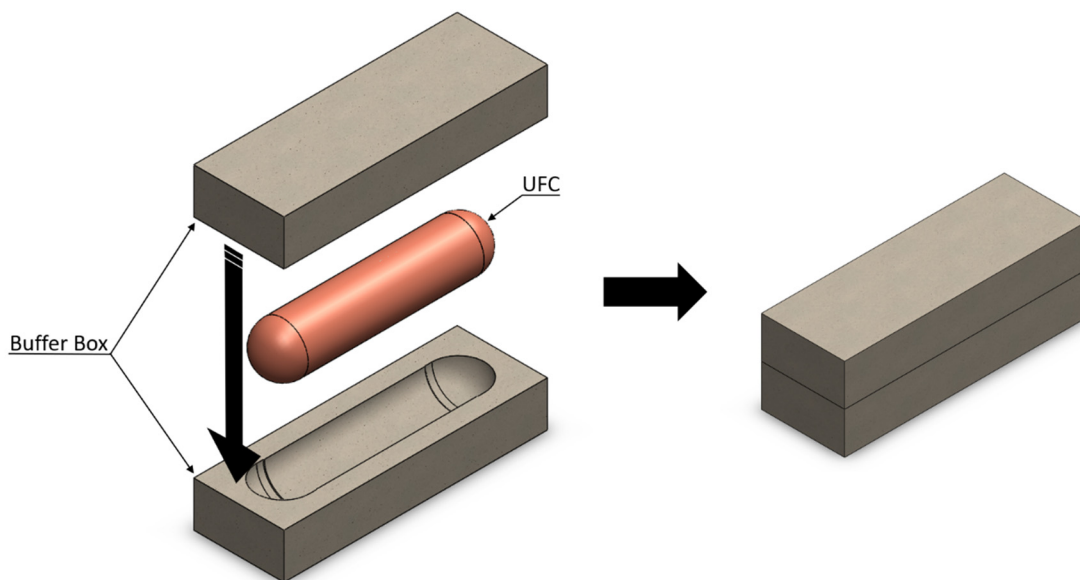
months. Auxiliary fans and ducting will be located in the underground tunnels and rooms, which will direct airflow into active placement rooms.

Used Fuel Container (UFC) Placement and Retrieval

The Used Fuel Container (UFC) consists of a carbon steel inner vessel with a copper coating fully bonded to the exterior surface. The steel vessel is designed to withstand the structural loads of the repository environment. The copper coating will function as a corrosion-resistant barrier to protect the steel vessel from corroding in the repository environment. The minimum thickness of the copper coating is 3 mm.

The UFC can hold 48 CANDU fuel bundles, distributed in four layers with 12 bundles per layer. The used fuel bundles are secured in place by an internal steel structure called an Insert.

Prior to underground transfer, the UFC will be pre-packaged into a rectangular shaped buffer box. The Buffer Box will be comprised of HCB formed into blocks with a machined cavity to house the UFC. The dimensions of the Buffer Box are approximately 1 m x 1 m x 2.9 m.



Used Fuel Container within Bentonite Buffer Box

Conceptual designs for the safe transfer and placement of the UFCs have been developed based on a review of proven nuclear industry material handling concepts, as well as related work by other national radioactive waste management organizations.

The transfer and placement technology will be refined and demonstrated in a mock-up of the placement room in a surfaced-based proof test facility and in the UDF prior to operations. The technology will also consider the potential retrieval of the UFCs from the repository placement rooms for subsequent return to the DGR's surface facilities. The intended retrieval approach may allow re-use of some of the container placement and mining equipment depending on time since placement.

Operational Safety and Radiation Protection

During the operational phase and the period of extended monitoring, there will be a numerous management systems and programs to ensure facility operational control and safety. These will include

- Worker occupational health and safety;
- Environmental monitoring at the surface and underground;
- Nuclear material safeguards;
- Radiation protection;
- Site security and emergency response planning; and
- Support systems including fire detection and suppression.

Radiological calculations have been carried out on selected aspects of the DGR's design elements to confirm that the potential whole-body dose for facility employees during normal operations at the DGR will be well below the limits established by the Canadian Nuclear Safety Commission (CNSC). The design includes sufficient shielding and use of remote operations to keep doses As Low As Reasonably Achievable (ALARA) in accordance with CNSC guidance (CNSC, 2021a) and the most recent recommendations of the International Commission on Radiological Protection (ICRP).

Extended Monitoring, Decommissioning and Closure

After used fuel placement activities are complete, there will be a period of extended monitoring. Following the receipt of regulatory approval, the DGR facility will be decommissioned, and the underground repository sealed. When sealing or closure of the repository is complete, the site will be available for surface use. These post-placement activities will take place in the following order, with assumed durations as shown:

- 70-year or more extended monitoring period;
- 10-year decommissioning period;
- 15-year closure period; and
- Post-closure period.

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DEFINITIONS AND ACRONYMS

AECL	Atomic Energy of Canada Limited.
AGV	Automated Guided Vehicle
ALARA	As Low As Reasonably Achievable
ANFO	High impact explosive made of a mixture of ammonium nitrate and fuel oil
AOO	Anticipated Operational Occurrences
APM	Adaptive Phased Management
Backfill	An engineered mixture (solid or loose) designed to infill a void
Basket	Cylindrical system holding used nuclear fuel in a vertical orientation
BB	Buffer Box
Bentonite	A swelling clay material used as a sealing material
BTP	Basket Transportation Package
Bulkhead	A concrete plug
Cage	Shaft conveyance used to move personnel and material underground
CANDU	CANada Deuterium Uranium
Cask	Mobile container for used fuel storage or transfer; typically shielded
CCA	Contamination Control Area
CCTV	Closed circuit television
CIP	Cold Isostatic Press
CNSC	Canadian Nuclear Safety Commission
Collar	The shaft opening at surface and the structure that supports the headframe
D&C	Decommissioning and closure
DBF	Dense backfill
DGR	Deep Geological Repository
Drill and Blast	Rock excavation by loading and detonating drill holes with explosive
EDZ	Excavation damage zone
ERMA	Excavated Rock Management Area
ERT	Emergency Response Team
FAR	Fresh Air Raise
Geosphere	The rock environment the DGR will be located within
GFM	Gap fill material
Grizzly	Heavy duty grate to stop oversize rock from falling into a muck pass
HCB	Highly compacted bentonite
HDPE	High-Density Polyethylene
Headframe	Tower structure that supports a hoisting operation, situated above the shaft
Heading	A tunnel that is being developed

HEPA	High efficiency particulate air (filter)
Hoek-Brown	Rock mass strength criteria
Hot Cell	An isolated and shielded room for contaminated (radioactive) material and equipment
HVAC	Heating, ventilation and air conditioning
IAEA	International Atomic Energy Agency
ILW	Intermediate level waste
Jumbo	A mechanized drilling machine
kg	Kilogram
kV	Kilovolts
L&ILW	Low and intermediate level waste
LAN	Local area network
LHD	Load / haul / dump unit (low-profile version of a surface front end loader)
LHHP	Low heat high performance (concrete)
LLW	Low-level waste
Loading Pocket	An underground assembly next to shaft to transfer excavated rock into skips
m / mm	Metre(s) / millimetre(s)
m ² / m ³	Square metre(s) / cubic metre(s)
Mbgs	Metres below ground surface
Module	Rack system holding used fuel bundles within a rectangular framework
MPa	Megapascal (unit of pressure)
Muck	Broken rock
NDE	Non-Destructive Examination
NEW	Nuclear Energy Worker
NFC	National Fire Code
NFPA	National Fire Protection Association
NWMO	Nuclear Waste Management Organization
OPG	Ontario Power Generation
Permeability	The ability of a rock or soil mass to transmit water
PLC	Programmable logic controller
PPE	Personal protective equipment
QA/QC	Quality Assurance / Quality Control
Raise	Vertical excavation used for ventilation, or to move personnel via ladders
Rock Bolt	A long anchor bolt installed in a drilled hole for local ground support of excavated face.
RMSA	Radioactive Material Storage Area
Safety Bays	Cut-out in tunnel for personnel to stand when equipment is passing
Scissor lift	Working platform that can be raised and lowered

Shaft	Vertical excavation for the hoisting of personnel, materials and rock
Shotcrete	Concrete sprayed on tunnel surfaces for ground support
SKB	Svensk Kärnbränslehantering AB (Swedish Nuclear Waste Management Org.)
Skip	Shaft conveyance mainly used for hoisting excavated rock to surface
SMCP	Sealing materials compaction plant
TBD	To be determined
TC	Transfer cask (intra-site)
UDF	Underground Demonstration Facility
UFC	Used Fuel Container (holds the used fuel bundles in repository)
UFIC	Used Fuel Inspection and Classification
UFPP	Used Fuel Packaging Plant
UFTP	Used Fuel Transportation Package
Wi-Fi	Trademark for wireless wide local area network
Working Face	The front end of a tunnel that is being developed

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1. INTRODUCTION

The Nuclear Waste Management Organization (NWMO) is implementing Adaptive Phased Management (APM), Canada's plan for the long-term management of its used nuclear fuel. The APM approach encompasses centralized containment and isolation of the used fuel in a Deep Geological Repository (DGR) located in a suitable rock formation to safely contain and isolate used fuel. In January 2020, the NWMO announced that the Ignace area in northwestern Ontario and South Bruce area in southern Ontario will undergo more detailed investigations to determine suitability for hosting the DGR. The Ignace area has a crystalline rock geosphere while the South Bruce area has a sedimentary rock geosphere. This report describes DGR facility concepts for these two rock types.

The NWMO has adopted a Used Fuel Container (UFC) design that provides containment for 48 CANDU used fuel bundles. Prior to transfer to the underground repository, the UFCs will be pre-packaged into rectangular shaped bentonite buffer boxes to facilitate placement inside the underground placement rooms. The repository is assumed to be located in either a crystalline or sedimentary rock geosphere at a nominal depth of 500 m.

This report describes the concept for the facilities and infrastructure needed to safely receive, repackage, and place the used nuclear fuel, as transported from reactor storage sites, in an underground repository.

The report is organized as follows:

- Section 2 lists the main design basis and boundary limits that form the conceptual design.
- Section 3 addresses the proposed surface facilities including the Used Fuel Packaging Plant (UFPP), which will receive and process the incoming used fuel, and then package the used fuel inside the UFCs and Buffer Boxes.
- Section 4 describes the shafts and hoists that will service the underground repository.
- Section 5 provides an overview of the underground repository and supporting ventilation system.
- Section 6 describes the transfer of UFC/Buffer Box Transfer Casks to the underground repository and emplacement inside a placement room. This section also describes the process to seal the placement room.
- Section 7 addresses the potential retrieval of UFCs from the repository.
- Section 8 describes site security and safeguard features.
- Section 9 addresses operational safety and monitoring systems.
- Section 10 addresses the topics of decommissioning and closure of the surface and underground facilities.
- Key technical references are listed in the References section.
- Appendix A provides further information on the UFC/Buffer Box design.

2. DESIGN BASIS

The following sections identify regulations, the main assumptions and other design criteria that form the basis for the conceptual design work presented in this document. Battery limits (the scope of design work) are also discussed.

2.1 ACTS, REGULATIONS, CODES AND STANDARDS

The following are the key acts, regulations, codes and standards that are applicable to the design of the DGR facility:

- Nuclear Safety and Control Act, Canada Gazette Part III, Vol 139, 1997 and associated regulations;
- CNSC Radiation Protection Regulations (SOR/2000-203);
- Ontario Occupational Health and Safety Act, Regulations 854/90, Mines and Mining Plants;
- Ontario Occupational Health and Safety Act, Regulations 851/90, Industrial Establishments;
- National Fire Code of Canada (NFCC);
- National Building Code of Canada (NBCC);
- Ontario Electrical Safety Code (OESC);
- CSA N286-12 (R2017), Management system requirements for nuclear facilities;
- CSA N288.4 (R2019), Environmental Monitoring Programs at Nuclear Facilities and Uranium Mines and Mills;
- CSA N393-13 (R2018), Fire protection for facilities that process, handle, or store nuclear substances;
- CSA C22.1, Canadian Electrical Code (CEC), Part I;
- CSA N292 series, covering the principles for the management of radioactive waste and irradiated fuel;
- Nuclear Security Regulations;
- Class I Nuclear Facilities and Prescribed Equipment Regulations;

2.2 DESIGN ASSUMPTIONS AND CONSTRAINTS

The primary assumptions that formed the basis for the conceptual design described in this report are as follows:

2.2.1 Used Fuel Characteristics

- The used fuel inventory to be accommodated comprises 5.5 million CANDU fuel bundles (Gobien and Ion, 2020);
- All used fuel bundles are a minimum of 10 years out-of-reactor prior to shipment;
- The used fuel is in the form of CANDU fuel bundles (Figure 1).



Figure 1: CANDU Fuel Bundle

2.2.2 Modules and Basket Configurations and Transportation Packages

- Ontario Power Generation (OPG) owned used fuel is stored and will be transported in a rectangular racking system known as a module, shown in Figure 2. Each module holds 96 fuel bundles in a horizontal orientation. Used Fuel Transportation Packages (UFTP) are certified for road transport and can transport 2 modules for a total of 192 fuel bundles to the repository.

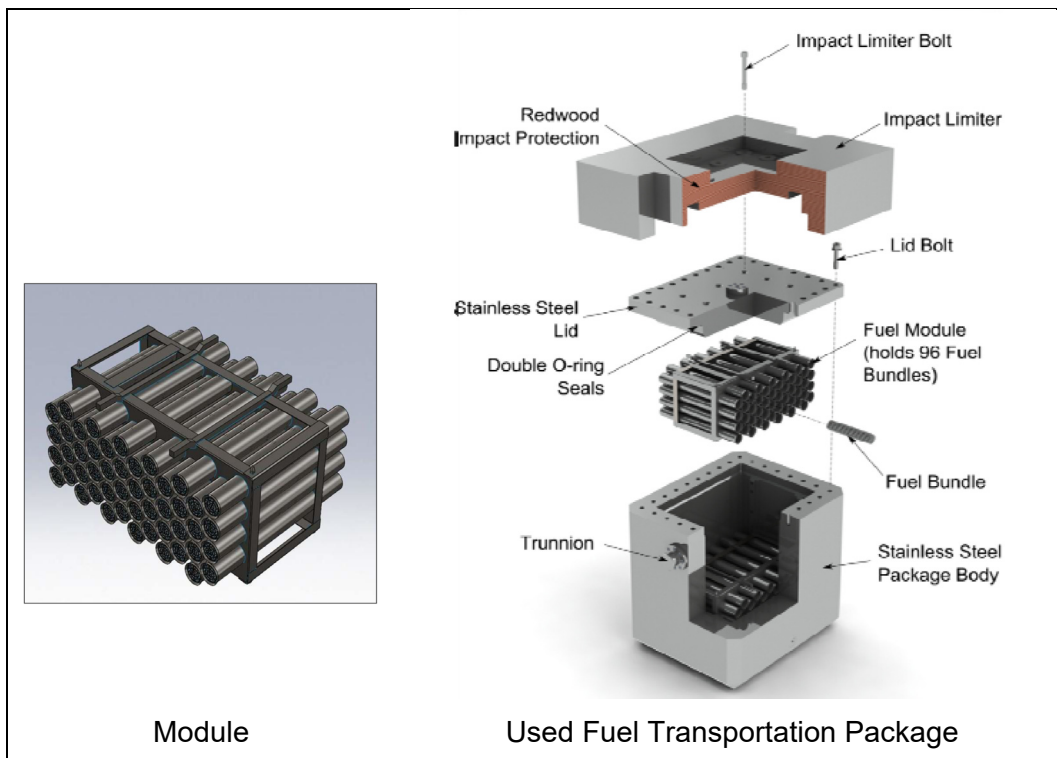


Figure 2: Module and Used Fuel Transportation Package

- Non-OPG owned used fuel is stored and will be transported in a cylindrical system known as a basket, shown in Figure 3. A typical basket holds 60 used fuel bundles in the vertical orientation. Basket Transportation Packages (BTP) are in the conceptual design stage and are assumed to be certified for road transport. It is assumed that the BTP can transport 2 baskets (for a maximum of 120 fuel bundles) by road to the repository.

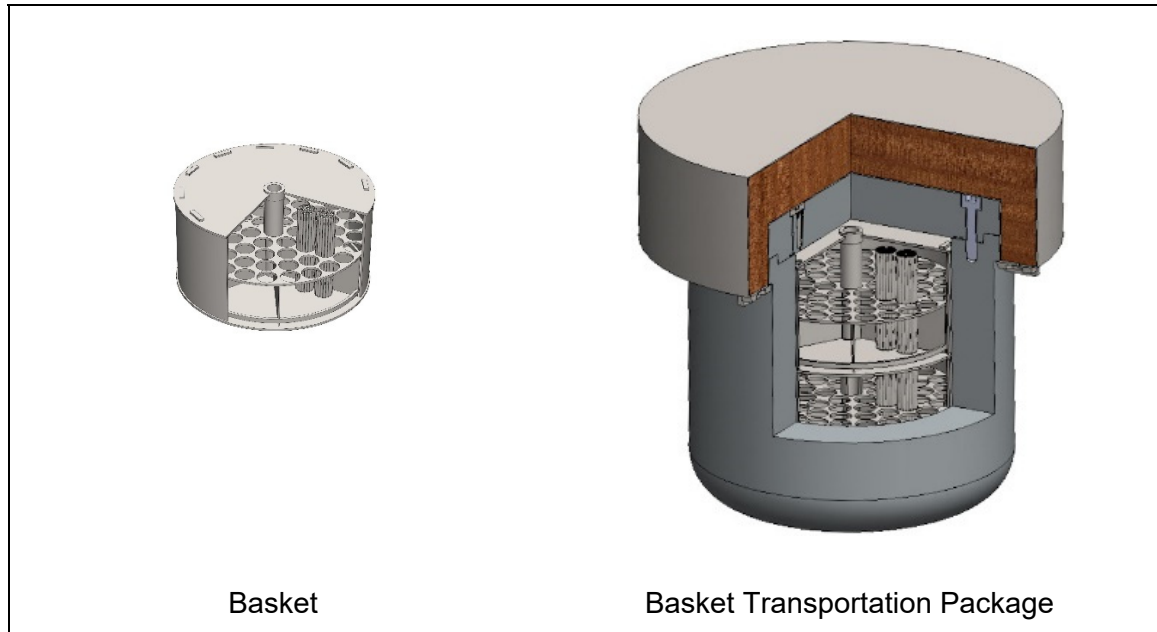


Figure 3: Basket and Basket Transportation Package

2.2.3 Used Fuel Handling, Packaging and Placement

- The used fuel will be repackaged at the Used Fuel Packaging Plant (UFPP) into Used Fuel Containers (UFC);
- The UFC will be a copper coated steel vessel with a steel insert that holds the fuel (see Appendix A);
- Prior to transfer underground, the UFC will be pre-packaged into a two-piece rectangular shaped buffer box made from highly compacted bentonite (HCB) blocks with a machined cavity to house the UFC. The Buffer Box dimensions will be approximately 1 m x 1 m x 2.9 m and each box will have an approximate loaded mass of about 8 tonnes;
- Design of operational systems and engineered barriers are based on an average thermal output of all the used fuel bundles in a used fuel container, which is equivalent to that of a 37 element CANDU fuel bundle with a burnup of 220 MWh/kgU and a storage time of 30 years from discharge.
- Empty storage modules and baskets (used in the delivery of used fuel bundles) will be processed in a dedicated area within or attached the UFPP and then sent off site for recycling, re-use, or long-term waste management;
- In the event that filled UFCs are returned from the underground repository (for example as part of a retrieval program), it shall be possible to modify the UFPP so that packaging process can be reversed in order to cut open and unload the UFCs;

- The UFPP will be designed with the principle that any abnormal anticipated operational occurrences (AOO) shall not lead to serious consequences for the environment, personnel or the plant itself;
- A rate of placement equivalent to 120,000 used fuel bundles per year will be accommodated. This is equivalent to 2,500 UFCs (in buffer boxes) placed per year (48 used fuel bundles per UFC);
- An average of 10 UFCs will be placed in the repository per day based on the assumption there are 250 working days each year;
- Each UFC/buffer box will be transferred inside a shielded transfer cask in a horizontal position on a trolley from the UFPP to the entrance of the placement room.

2.2.4 Underground Repository

- For the purposes of this conceptual design work, it is assumed that the repository will be located either within a high-quality sparsely fractured crystalline or within a sedimentary rock geosphere which has a thick homogenous and competent host rock formation;
- The underground repository will be constructed at a nominal depth of 500 m below ground surface subject to site specific conditions (shaft bottom allowances for sumps, etc. will be below this elevation);
- The repository's placement rooms, and access tunnels will have a pre-defined minimum stand-off distance from a major fracture and/or investigation borehole;
- To the extent practical and necessary, placement rooms will be oriented with respect to the in-situ stress fields so as to minimize stress concentration around openings to promote long-term stability and minimize rock support requirements;
- Placement room will be designed to minimize stress levels and excavation damage at the rock surface; and
- Flexibility and adaptability will be provided in the repository layout so that changes can be implemented if necessary (e.g., due to adverse rock conditions).

2.2.5 Used Fuel Placement and Retrieval

- An in-room horizontal placement method will be utilized in the underground repository;
- Buffer boxes containing the UFCs will be stacked between HCB spacer blocks and surrounded by granular GFM;
- The placement room cross-section will be sized to provide the required clearances for excavation, insertion of sealing materials and UFC placement. It will also contribute to excavation stability;
- The design includes a space allowance equal to about 10% of each room to account for possible groundwater seepage or unsuitable rock conditions (this assumption increases the total number of placement positions to be established);
- UFC placement configurations will ensure temperature on the UFC container surfaces does not exceed 100°C;
- Upon completion of each placement room, a placement room seal will be constructed at the room entrance to allow bentonite to develop swelling pressure and limit migration of radioactivity out of the room including migration via the excavation damage zone (EDZ); and
- The DGR design will allow the potential for retrieval of used fuel containers prior to closure of the repository.

2.2.6 Radiation Shielding

- In compliance with REGDOC-2.7.1 (CNSC, 2021a), shielding structures will be designed to ensure that doses are maintained to As Low As Reasonably Achievable (ALARA) during both normal operations and AOO. Shielding will be integrated into the design of structures, equipment and containers, with consideration of time and distance within the fuel handling procedures.
- Use of remote handling techniques will be considered;
- The shielding design will be optimized using annual effective dose constraints of 5 mSv for Nuclear Energy Workers (NEWs) and 0.1 mSv for workers that are not designated as NEWs;
- Shielding design of transfer casks (both UFC and UFC/Buffer Box Transfer Casks) assumes that 10-year-old used fuel with a burnup of 290 MWh/kgU is handled (Heckman & Edward, 2020). The external dose rates on the transfer casks are limited to 2000 μ Sv/h on contact and 100 μ Sv/h at 1m; and
- In order to simplify construction, maintenance and operations, shielding will be comprised of ordinary materials (e.g., steel, lead, concrete) wherever possible and be designed for easy decontamination of exposed surfaces.

2.2.7 Supporting Operations

- A hoisting speed of not more than 2.5 m/s will be used for movement of transfer casks with buffer boxes down to the underground repository;
- The shaft complexes will be designed to function during the construction phase and the operations phase including the period of extended monitoring;
- Service Shaft and Exhaust Ventilation Shaft auxiliary hoisting systems will employ Blair multi-rope hoists to eliminate the need for timber guides (required for single-rope drum hoisting systems) and thus reducing fire hazard inside shafts;
- Redundant services (i.e., duplicating services in the Service Shaft) will be located in the Exhaust Ventilation Shaft;
- Waste processing facilities will be capable of safely and efficiently handling, treating and packaging any generated low and intermediate level (non-fuel) waste prior to disposal in a suitable long-term waste management facility;
- Ventilation for the underground repository will provide effective dilution of contaminants and dissipation of heat to provide a comfortable working environment, and be kept under positive pressure;
- Raw material inventories will be adequate to compensate for any delivery delays due to adverse weather conditions; and
- Surface ponds with DGR surface facilities have been sized to accommodate a 1-in-500-year storm event.

2.2.8 Decommissioning and Closure

- After placement is complete, we have assumed a 70-year extended monitoring period during which underground access will be maintained and the placement rooms will be monitored;

- During this extended monitoring period, the capability to retrieve UFCs from placement rooms is maintained but will require increasing efforts as time advances; and
- To the degree that it is practical to do so, final decommissioning and closure of the DGR facility will return the site to natural conditions and there will be no provision for re-entry to underground repository after closure.

2.3 BATTERY LIMITS

The battery limits for the design work are essentially represented by the DGR's perimeter fence systems, which encompass practically all of the design elements outlined in this report with a few exceptions. These exceptions relate to the external off-site facilities (e.g., excavated rock management area) and transportation (Taylor, 2021).

3. SURFACE FACILITIES AND INFRASTRUCTURE

The DGR surface facility will include structures, systems, equipment and components for operation, maintenance, and long-term monitoring. Surface facilities are identified as either being in a Protected Area (i.e., a restricted area) or associated with the Balance of Site area. The differentiation being that all buildings or activities pertaining to the handling and storage of used nuclear fuel will be located in the Protected Area. The Protected Area will be located near the center of surface facilities site and will be surrounded by the Balance of Site area. The two areas will be separated for safety and security reasons (see Figure 4).

External facilities, located outside the DGR's perimeter fence, will also be required for support of repository construction and operation. Such facilities will include the Centre of Expertise and accommodation for construction personnel (if required), as well as, an Excavated Rock Management Area (ERMA).

The following section describes the primary surface facility components with the exception of the underground shafts, site security and safeguard features. The three Shaft Complexes (Main Shaft, Service Shaft and Exhaust Ventilation Shaft) are discussed in Section 4. Site security measures (fencing, security checkpoints, guardhouses, and monitoring rooms) and safeguard measures are described in Section 8.

3.1 GENERIC SITE LAYOUT

The generic DGR surface facility layout is shown in Figure 4 with component facilities identified in Table 1. The facility is laid out such that all buildings which handle, or store used nuclear fuel are located in the Protected Area. This area is separated from other surface facilities by a security fence, equipped with lighting and intruder detection systems. Personnel and vehicular access to the Protected Area will be strictly controlled by way of checkpoints and security gates provided with radiation monitors.

The layout of the buildings provides for the safe and efficient operation of the facility in terms of radiological zoning, material movement, traffic patterns and interaction between the services provided by the different buildings. The Service Shaft, Exhaust Ventilation Shaft, and the Main Shaft Complexes are the anchor points for the DGR's layout. The distance between the UFPP and the Main Shaft Complex, for example, has been kept to a minimum to accommodate the delivery of buffer boxes/UFCs.

The land required to accommodate the DGR surface facilities covers an area of approximately 625 m x 700 m as shown in Figure 4. A three-dimensional perspective of the surface facilities is provided as Figure 5.

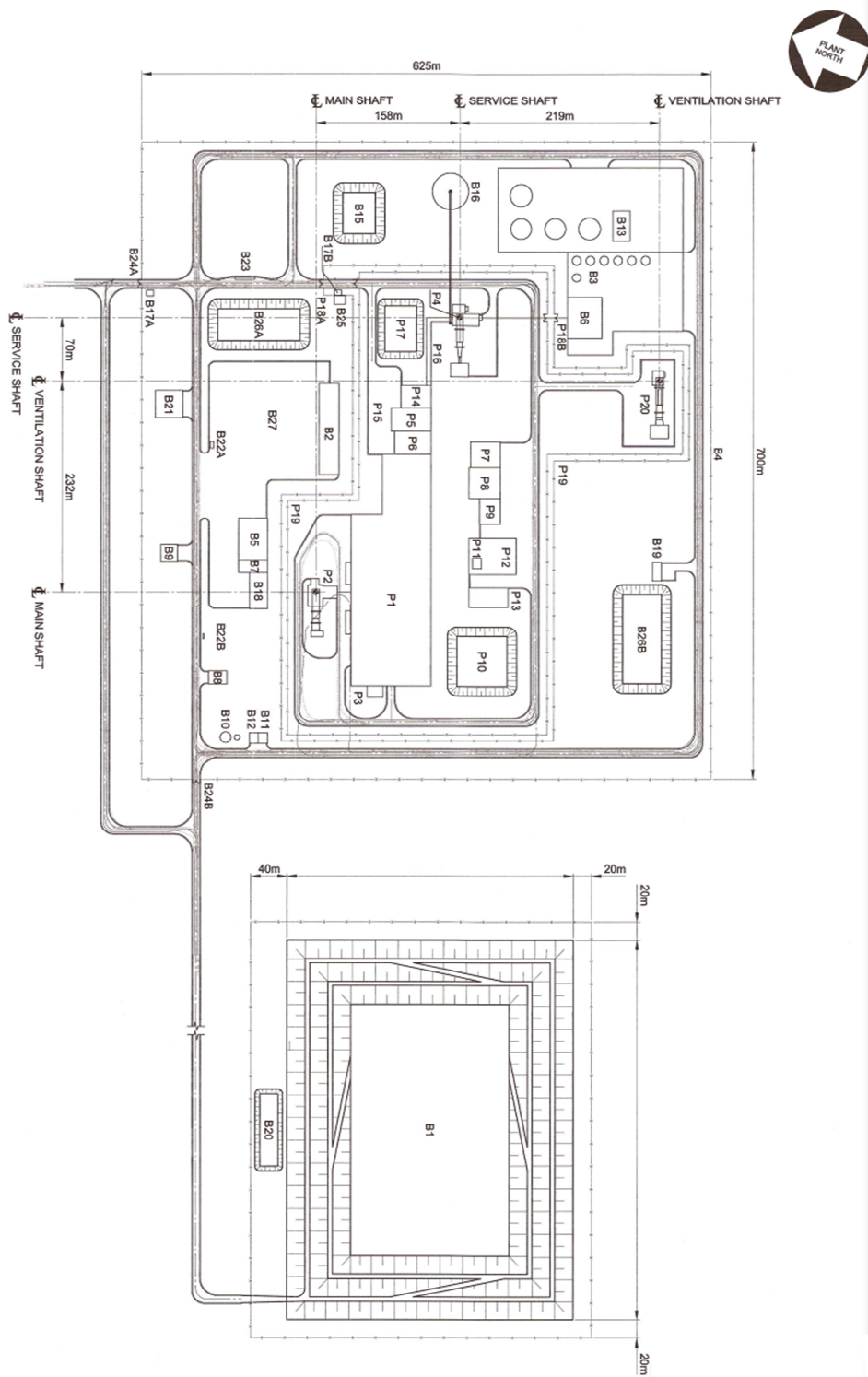


Figure 4: Surface Facilities (Generic) Site Layout

Table 1: Area Number and Description

Area	Protected Area	Area	Balance of Site
P1	Used Fuel Packaging Plant	B1	Excavated Rock Management Area (ERMA)
P2	Main Shaft Complex	B2	Administration Building including Firehall and Cafeteria
P3	Stack	B3	Sealing Material Storage Bins
P4	Service Shaft Complex	B4	Perimeter Fence
P5	Auxiliary Building	B5	Garage
P6	Active Solid Waste Handling Facility	B6	Sealing Material Compaction Plant
P7	Waste Management Area	B7	Warehouse and Hazardous Materials Storage Building
P8	Active Liquid Waste Treatment Building	B8	Air Compressor Building
P9	Low-Level Liquid Waste Storage Area	B9	Fuel Storage Tanks
P10	Stormwater Management Pond	B10	Water Storage Tanks
P11	Switchyard	B11	Water Treatment Plant
P12	Transformer Area	B12	Pump House
P13	Emergency Generators	B13	Concrete Batch Plant
P14	Quality Control Offices and Laboratory	B14	Not Used
P15	Parking	B15	Service Water Settling Pond
P16	Covered Corridor / Pedestrian Routes	B16	Excavated Rock Stockpile (Working)
P17	Mine De-watering Settling Pond	B17	Guardhouses (A, B)
P18	Security Checkpoints	B18	Storage Yard
P19	Double Security Fence	B19	Sewage Treatment Plant
P20	Ventilation Shaft Complex	B20	ERMA Stormwater Management Pond
		B21	Helicopter Pad
		B22	Bus Shelters (A, B)
		B23	Weigh Scale
		B24	Security Checkpoints
		B25	Security Monitoring Room
		B26	Stormwater Management Ponds (A, B)
		B27	Parking Area

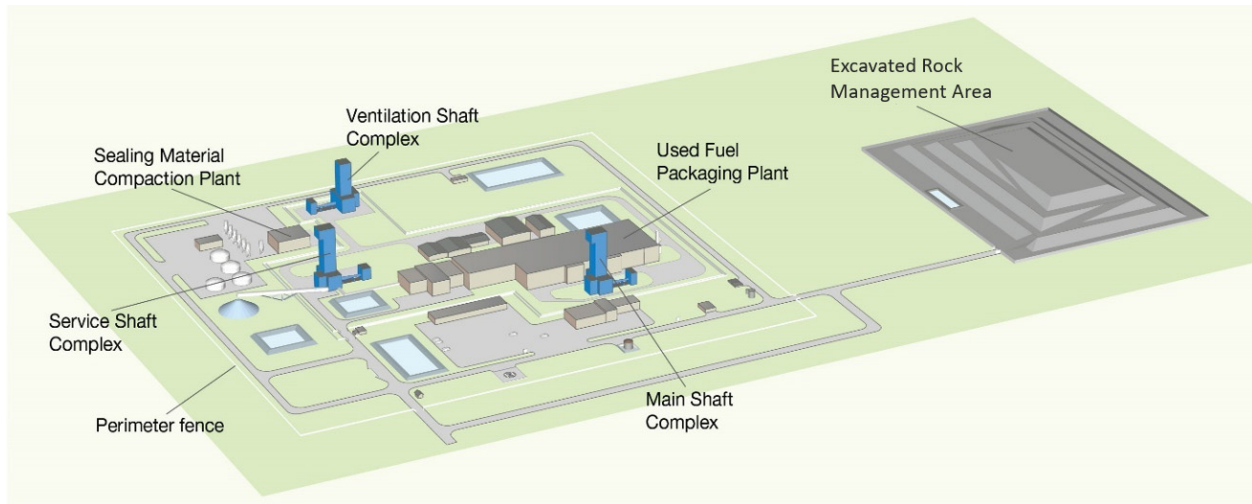


Figure 5: Deep Geological Repository Surface Facilities

3.2 USED FUEL PACKAGING PLANT (UFPP)

Area P1

The Used Fuel Packaging Plant (UFPP) is identified as Area P1 on the generic site layout shown in Figure 4. In the current conceptual design, the UFPP will be a single storey, reinforced concrete structure. The UFPP will contain the necessary provisions for receiving used nuclear fuel in certified road transportation packages (i.e., the Used Fuel Transportation Packages (UFTP) and Basket Transportation Packages (BTP)), transferring the fuel to UFCs, and assembling UFCs into Buffer Boxes for transfer underground to be emplaced in the DGR. The current UFPP layout is shown in Figure 6. The key process steps to achieve safe repackaging consist of:

- receiving and opening up the transportation packages in the UFTP/BTP Shipping and Receiving area;
- removing the used fuel and transferring them into the UFCs in the UFC Loading Cell;
- seal welding the loaded UFCs in the UFC Weld Cells;
- decontamination of the welded UFCs in the Decontamination cells;
- copper coating in the Copper Application cells;
- copper annealing in the Copper Annealing cells;
- assembling the UFC in the bentonite buffer box to be emplaced underground in the Buffer Box Storage, Handling and Dispatch area; and
- multiple inspection points, utilizing various non-destructive examination techniques, to verify that the packaging process achieves the specified safety and security requirements.

The UFPP will ensure that used fuel received from the reactor sites is properly packaged for emplacement in the DGR. This includes detection of damaged or defective used fuel and segregating these bundles for further processing, as required, prior to packaging and placement in the DGR.

All handling operations that involve used fuel will be completed within heavily shielded enclosures (cells). Fuel handling will use remote tooling. Transfers between the cells and will be completed

in shielded packages to minimize worker dose. All shielded cells will also be environmentally controlled by an active ventilation system to prevent the spread of airborne contamination.

The UFPP will also include the required auxiliary systems, like electrical power systems (regular, emergency and back-up), a central control room, waste management facility, and facilities for personnel and visitors. Maintenance on used fuel handling equipment will be performed within the confines of the UFPP. The provisions for the safe handling of any wastes generated as a result of packaging the used fuel or maintenance of the used fuel handling equipment will also be provided in the UFPP.

All areas of the UFPP will be classified, zoned, and controlled according to external dose rates and the potential for contamination. Ventilation systems will be according to the best engineering practice and latest standards for active ventilation systems. These standards specify negative pressure ranges for each area classification. Areas with the highest activity and contamination hazards will generally be kept at the most negative pressure.

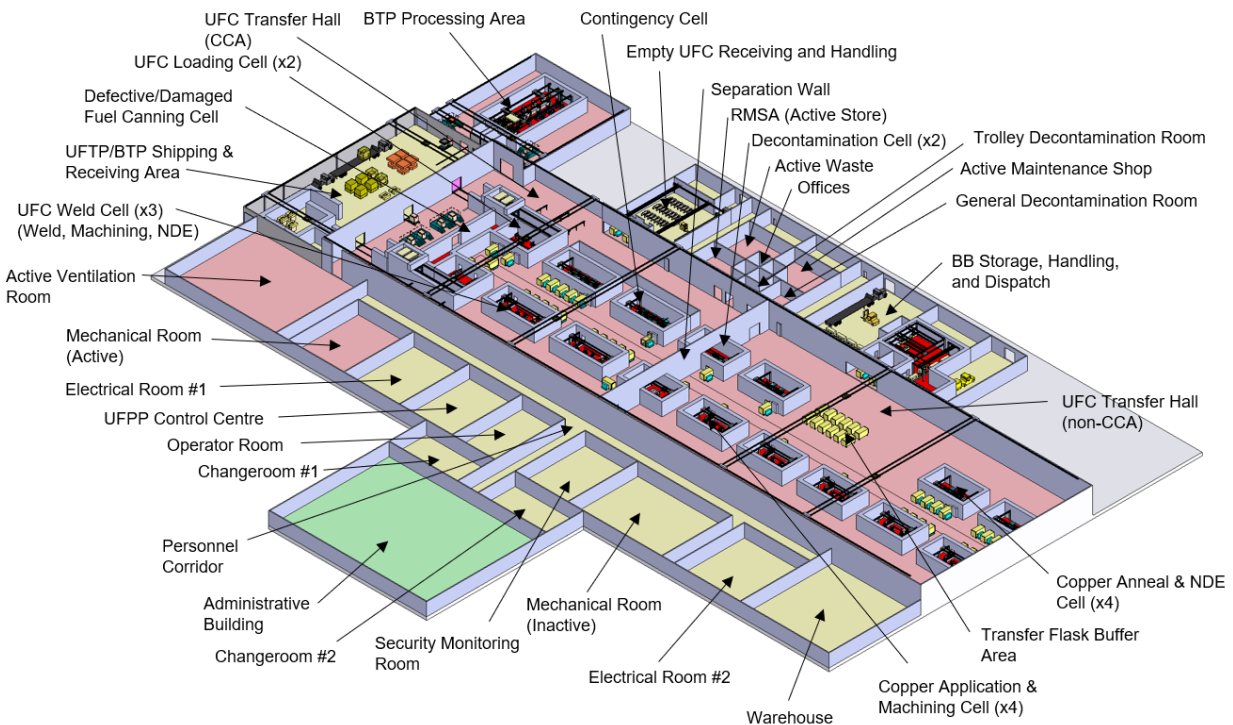


Figure 6: Layout of the Used Fuel Packaging Plant (UFPP)

3.2.1 Facility Throughput

The UFPP will have a lifetime throughput requirement of processing over 5.5 million used nuclear fuel bundles over the facility life of approximately 46 years. This will be accomplished by processing approximately 120,000 used nuclear fuel bundles into 2,500 UFCs on an annual basis. On average, 10 UFCs will be processed each workday.

The UFPP facility throughput is based on annual transportation shipping assumptions, as shown in Table 2. These annual shipping assumptions define the annual used fuel quantities to be transported from each interim storage facility and have been established for planning purposes which will be further refined closer to operations.

Table 2: Annual Transportation Shipping Assumptions

Interim Storage Facility	Transportation Package ⁽¹⁾	Total Used Fuel Transported (bundles)	Total Used Fuel Transported (shipments)	Start Year	Finish Year
Bruce	UFTP ⁽²⁾	2,907,650	15,147	2050	2088
Pickering	UFTP	902,148	4,699	2043	2050
Darlington	UFTP	1,268,801	6,610	2050	2088
Point Lepreau	BTP ⁽³⁾	258,820	2,157	2054	2066
Chalk River	BTP	7,187	90	2068	2068
Gentilly 1	BTP	3,213	43	2050	2050
Gentilly 2	BTP	129,925	1,083	2050	2054
Douglas Point	BTP	22,256	207	2067	2068
	Total:	5,500,000	30,036		

Note:

- (1) One transport package (UFTP or BTP) per shipment.
- (2) UFTP holds 2 modules (192 fuel bundles)
- (3) BTP holds 2 baskets. For Point Lepreau and Gentilly-2, baskets hold 60 bundles per basket. For Chalk River, Gentilly-1 and Douglas Point baskets hold fewer used fuel bundles (i.e., 40, 38, and 54 used fuel bundles, respectively).

These shipping assumptions are conceptual and are subject to future refinement and change.

The expected maximum annual throughputs are shown in Table 3. The maximum number of UFTPs and BTPs received at the UFPP, in any given year will be 625 and 260, respectively. The UFPP will receive and process up to 3 UFTPs and 2 BTPs per day.

Table 3: Throughput processing parameters for the UFPP

Item	Bundles per Unit	Throughput		
		Base Case Total	Annual	Daily
Bundle	1	5,500,000	120,000	480
UFC	48	~115,000	2,500	10
Basket	60	~7,200	520	4
Module	96	~53,000	1,250	6
BTP	120	~3,600	260	2
UFTP	192	~26,500	625	3

* Based on assumption of 250 UFPP UFC processing days working days per year.
 **: UFTP/BTP shipments fluctuate depending on year (i.e., the facilities actively shipping). The UFTP, BTP, Basket (typical), and Modules presented in the above represent maximum yearly throughputs.

3.2.2 UFPP Process Flow Overview

The UFPP concept adopts a modular manufacturing approach, utilizing multiple duplicate packaging systems, to ensure redundancy to achieve the required processing throughput. The key used fuel processing steps to achieve repackaging in the UFC and bentonite buffer box ready for placement in the DGR are shown in Figure 7.

3.2.3 UFPP Process Descriptions

3.2.3.1 Receipt of UFTP/BTP and used fuel module/basket unloading

Used fuel will be transported from the reactor sites via certified road transportation packages (i.e., UFTP and BTP). The trucks, trailers, and packages will arrive at the Transportation Package (UFTP/BTP) Shipping and Receiving area in the UFPP.

The Shipping and Receiving area, as shown in Figure 8 will contain a laydown area and short-term handling space directly adjacent to the transport trailer unloading area. This space will be used to handle short term storage needs of transportation packages. This includes space for unpacking transportation packages with consideration for weather covers, impact limiters and specialized handling tools. The UFPP will also have additional shielded space (laydown area) available to minimize worker dose consistent with ALARA principles. A large overhead crane will sit above the entire shipping and receiving area. The overhead crane will be the main system used to move UFTPs, BTPs and supporting equipment around this area of the UFPP.

After the UFTP or BTP are removed from the transport trailer, the packages will be placed on one of two work platforms. At the platforms, International Atomic Energy Agency (IAEA) safeguard seals will be inspected and removed.

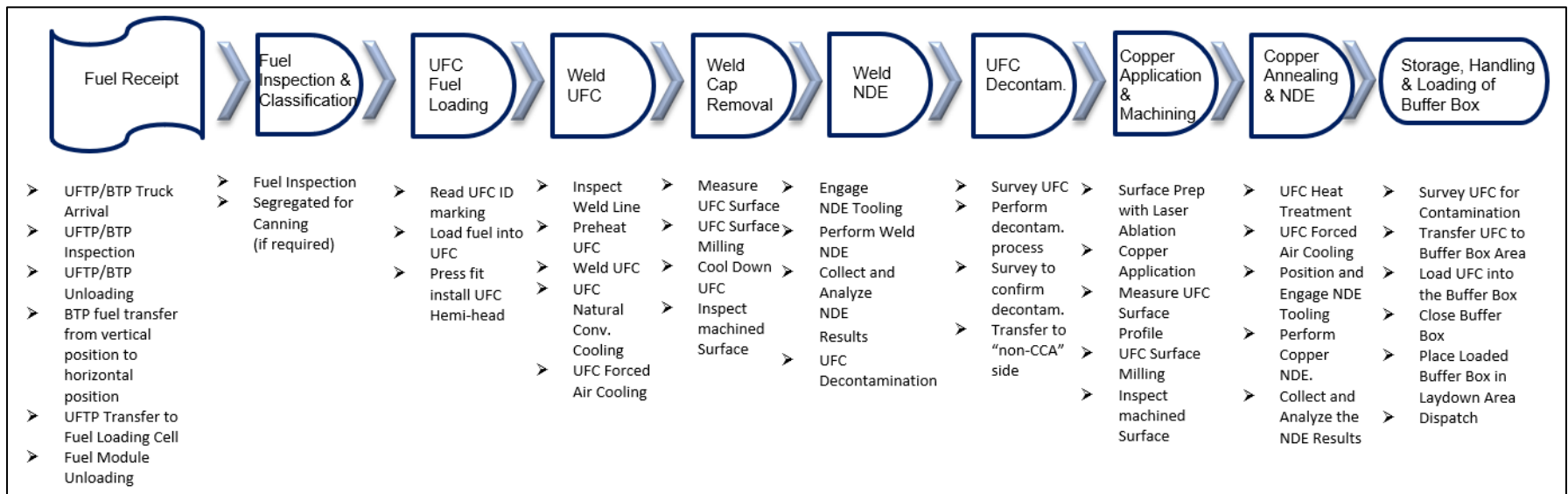


Figure 7: Used Fuel processing activities in the Used Fuel Packaging Plant (UFPP)

After IAEA seals are inspected and removed, the UFTP will be processed in the following manner:

- The impact limiter bolts, and impact limiter will be removed.
- The lid lift and vent port adaptors will then be installed.
- UFTPs will then be transferred by crane onto a trolley which will enter the UFC transfer hall for further processing.
- Within the UFTP unloading cell, specialized tools will unbolt the UFTP lid, lift the lid and transfer the modules from the UFTP cavity onto the module worktables in the UFC Loading Cells.
- The used fuel bundles will be unloaded from the modules
- The empty modules will then be transferred to the waste management facility for processing. The modules will be either sent off site for recycling/reuse or long-term waste management.

After IAEA seals are inspected and removed, used fuel in BTPs will undergo a separate process prior to unloading because the used fuel is contained inside a secondary seal-welded steel basket and housed in a vertical orientation. The BTPs will be processed in the following manner:

- The BTP will be transferred to a BTP processing area.
- BTP processing tools will cut open the baskets and reorient the fuel to a horizontal position in a module(s) to conform with the used fuel received in UFTPs.
- The reoriented fuel will then be transferred to the UFTP unloading cell where it will undergo the same process as UFTPs.
- The empty baskets will then be transferred to the waste management facility for processing. The baskets will be either sent off site for recycling/reuse or long-term waste management.
- The UFPP will have one BTP processing area and two independent UFTP unloading areas.

Empty UFTPs and BTPs will be returned to the Shipping and Receiving area after their lids are reseated, bolts tightened and decontaminated. Packages will be reloaded back onto the empty trailers (with impact limiters and weather covers) and returned to the reactor sites for reloading.

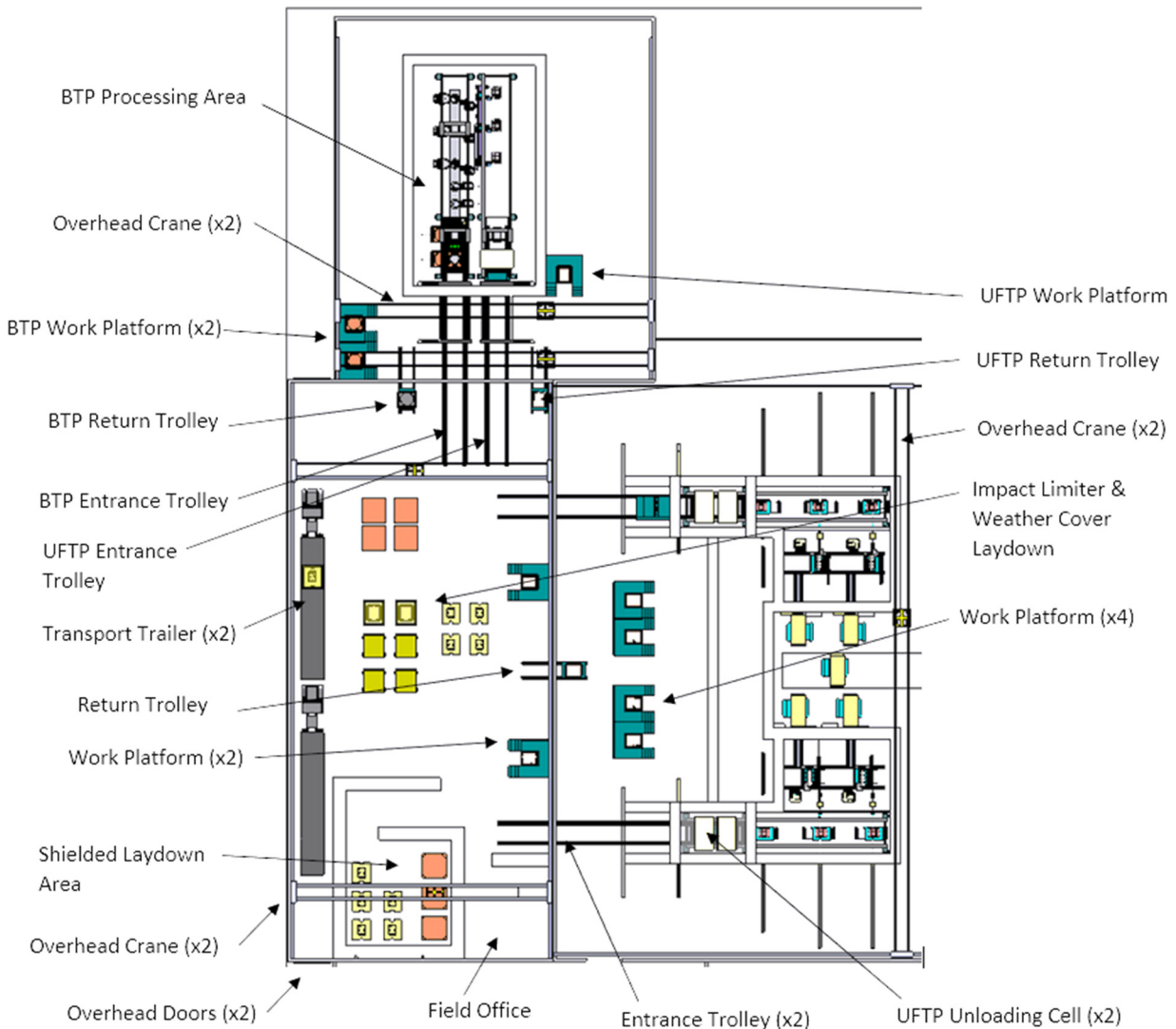


Figure 8: Transportation Package (UFTP/BTP) Shipping & Receiving Area

3.2.3.2 Used Fuel Inspection and UFC Loading

The UFPP will contain two UFC loading cells designed to transfer used fuel into UFCs, as shown in Figure 9, from one of the two UFTP unloading cells.

Each UFC loading cell will contain two Used Fuel Inspection and Classification (UFIC) systems integrated with two UFC loading system. The entire system will inspect and load approximately 10 UFCs per day (2.5 UFCs per UFIC and UFC loading system).

The Used Fuel Loading system will consist of two positioning tables, a push ram and stationary guide sleeve. The positioning tables and guide sleeves ensure alignment between the module and UFC insert.

The UFC Loading process will begin with the push ram pushing the used fuel bundles from the modules to the UFIC system. The UFIC system will then perform the following inspection on each the used fuel bundle:

- a) bundle identification,
- b) radioactivity measurement, and
- c) examination for damage / defect.

If the bundle passes the inspection criteria, the used fuel will be loaded into the UFC insert. If the used fuel does not pass the inspection, the fuel will be segregated for further processing and returned to the fuel module.

Once fully loaded, the UFC will be temporarily closed by press-fitting the Hemi-Head cap onto the UFC Lower Assembly. The key components of the UFC are shown in Figure 10.

The assembled UFC will be loaded into a shielded UFC Transfer Cask and moved by an Automated Guided Vehicle (AGV) (also called the intra-plant transfer system) through the UFC Transfer Hall to an available UFC Weld Cell. If all weld cells are in use, then the transfer cask will be placed into a buffer position until a Weld Cell becomes available. The shielded UFC transfer cask will keep personnel working in the vicinity safe from radioactivity. The AGV will move the shielded transfer cask, containing the UFC, between the various work cells in the UFPP.

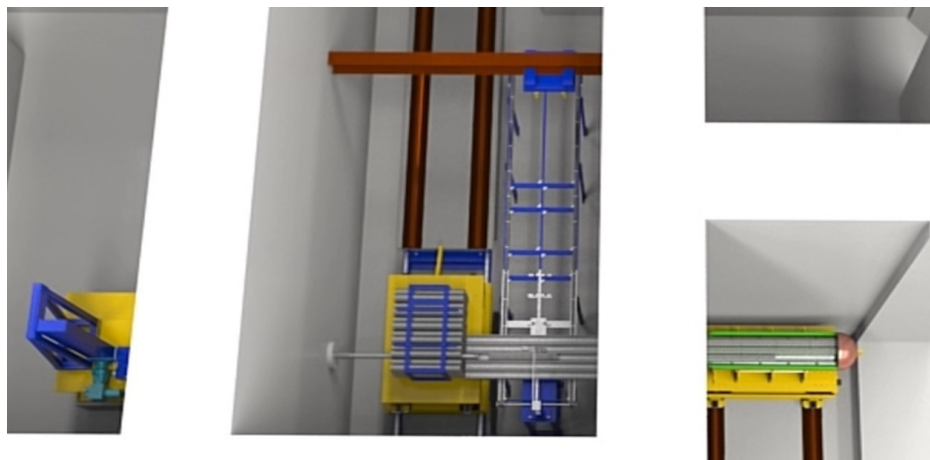


Figure 9: Fuel Transfer into Used Fuel Container

Description of Figure 9:

- a) Room at left of figure houses the equipment to operate the push ram that penetrates the work cell shielding wall.
- b) A used fuel module loaded with fuel bundles is located on a positioning table in the shielded work cell (center). There will be two (2) module positioning worktables per cell.
- c) Bundles are pushed by the ram into the UFC located in the shielded work cell at right of figure. The UFC is shown in a cut-way view with top half of the UFC removed for the purpose of this illustration.

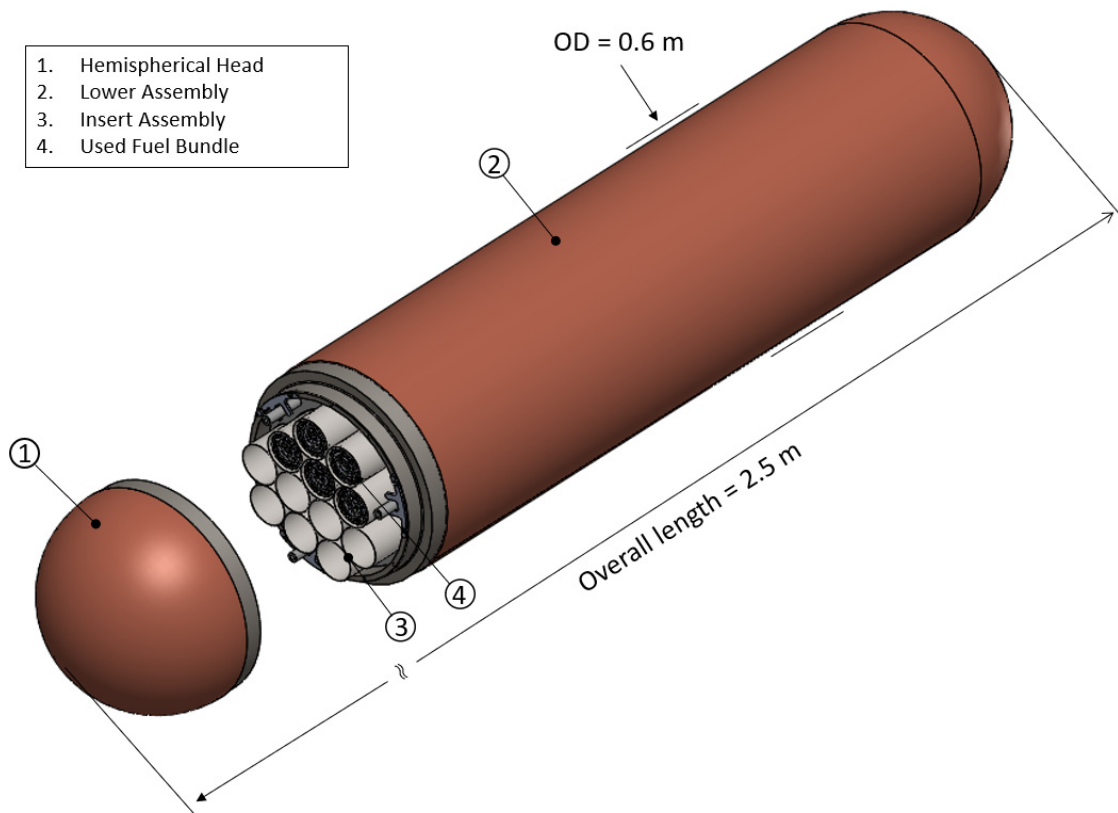


Figure 10: Used Fuel Container Components

3.2.3.3 UFC Weld Cell

After completion of the UFC fuel loading, the UFC will be transferred to one of three UFC Weld Cells using the intra-plant transfer system. Upon arriving at the UFC Weld Cell, the UFC will be extracted from the shielded cask into the shielded process cell and transferred onto a rotary positioner. The rotary positioner will transfer the UFC between the various workstations within the weld cell and will provide the rotary feed motion required for each process of applying the closure weld. The UFC Weld Cell and process steps are shown in Figure 11 and Figure 12.

The UFC on the rotary positioner and pre-heat worktable will align using a camera system to verify the joint line fit-up. Then the UFC is preheated using an induction coil while the UFC is rotated to ensure even heat distribution until the required temperature is reached.

The pre-heat coils will then be retracted while the weld arm is extended to the UFC. While the UFC continues its rotation, the welding system will weld along the joint line between the UFC hemi-head and UFC Lower Assembly. When welding is complete the UFC will be cooled prior to moving to the next operation.

The rotary positioner will then move the UFC to the weld machining worktable where a dry milling process will remove the weld cap to create a smooth profile at the UFC weld joint. The finished surface will allow for the weld to be inspected and, if acceptable, covered by copper coating.

A series of Non-Destructive Examination (NDE) inspection processes will verify the weld meets design requirements (i.e., adequate depth and have no defects that would compromise the integrity of the UFC). After weld NDE data is collected, the UFC will be placed back into the shielded transfer cask and moved to a waiting area while the NDE data is being processed and reviewed. The next UFC will then be allowed to be processed in the now empty weld cell.

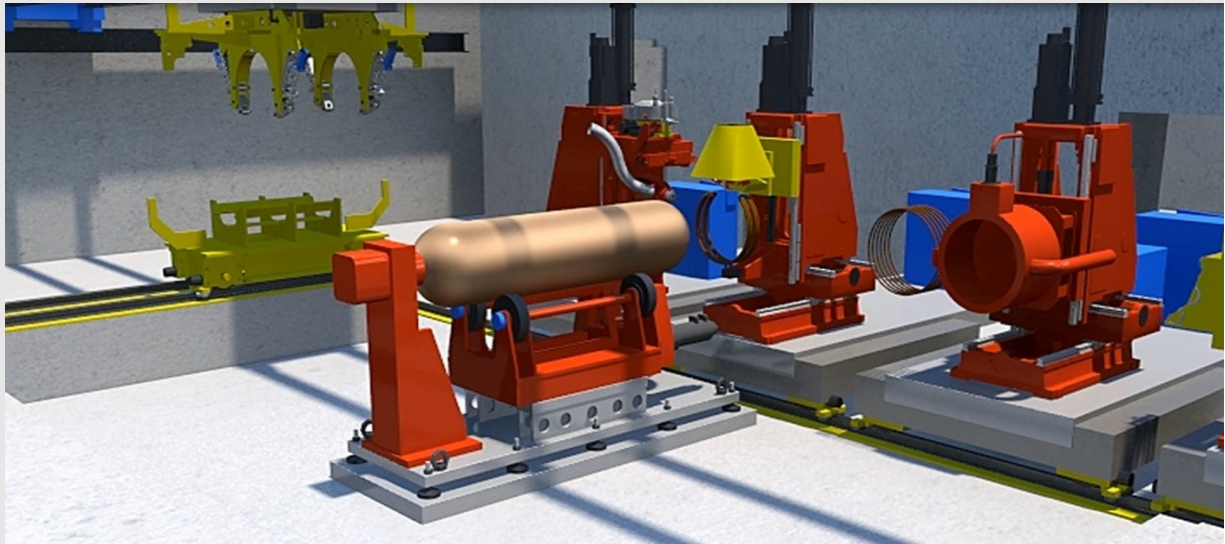


Figure 11: Used Fuel Container Well Cell arrangement with various process worktables

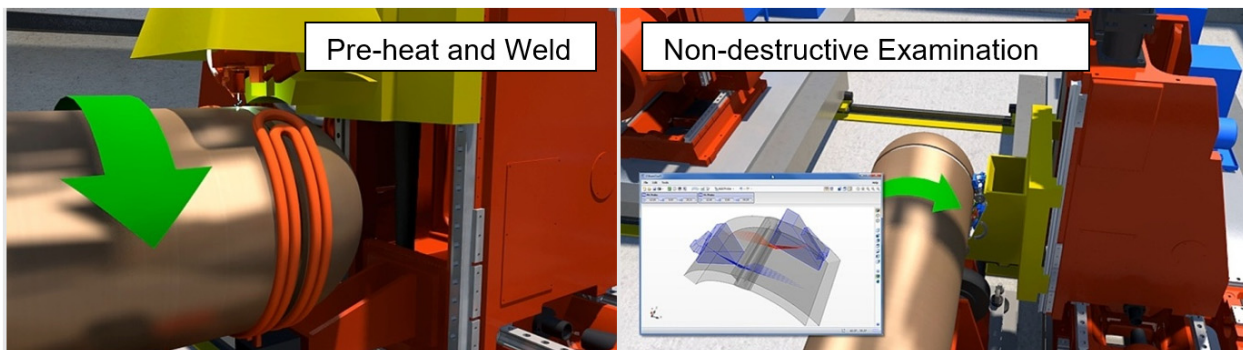


Figure 12: The Pre-heat & Weld Worktable and Weld NDE Worktable

3.2.3.4 UFC Decontamination Cell

The UFC Decontamination cell will remove radiological and non-radiological surface contaminants from the sealed UFC. This system will limit the risk of surface contamination entering subsequent processing cells and other systems within the UFPP.

The UFC Decontamination cell will be the separating barrier between the Contamination Control Area (CCA) side of the UFC Transfer Hall where the UFC will be loaded and welded from the non-CCA side. Decontamination of the UFC exterior will be accomplished within one of two independent UFC Decontamination cells as shown in Figure 13.

The UFC will be decontaminated using remote tooling and surveyed to confirm the UFC is free of contamination. A “clean side” lift will then transfer the UFC across a contamination barrier wall spanning the width of the UFC transfer hall and place the UFC into another shielded UFC transfer cask for movement throughout the “non-CCA” side of the facility, where the remainder of the processing steps will be completed. While the non-CCA side is expected to be free of radioactive contaminants, best practices will include regular monitoring through the UFPP.

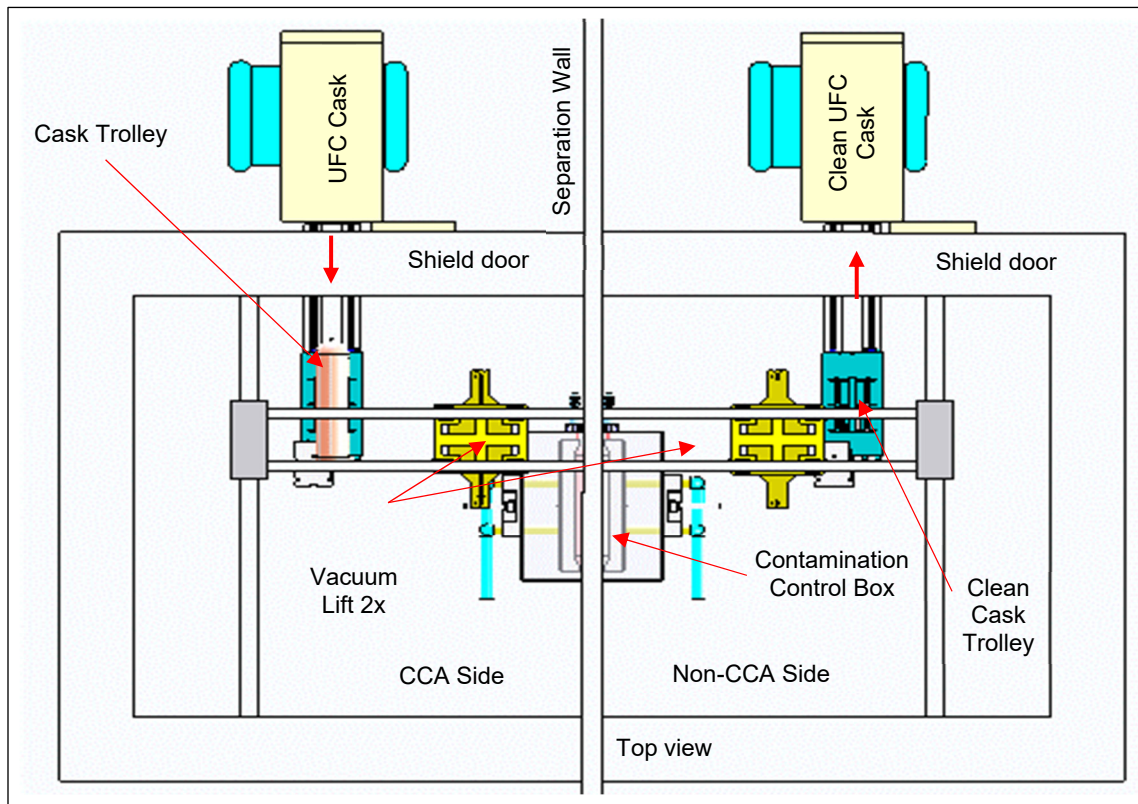


Figure 13: UFC Decontamination Cell

3.2.3.5 UFC Copper Application and Machining Cell

After the UFC is decontaminated, it will enter one of four UFC Copper Application and Machining shielded work cells to undergo the process of completing the corrosion-resistant copper barrier, as shown in Figure 14. The UFC will be placed onto a rotary positioner to be transferred between worktables within the cell.

The UFC’s machined weld area will be coated in copper using gas dynamic cold spray (cold spray) application process up to the required thickness. Following copper application, the UFC will be transferred to the machining worktable where the applied copper will be machined smooth to allow inspection.

After completion of the machining process, the UFC will be loaded back into a shielded transfer cask and moved to a UFC Copper Annealing / NDE work cell.

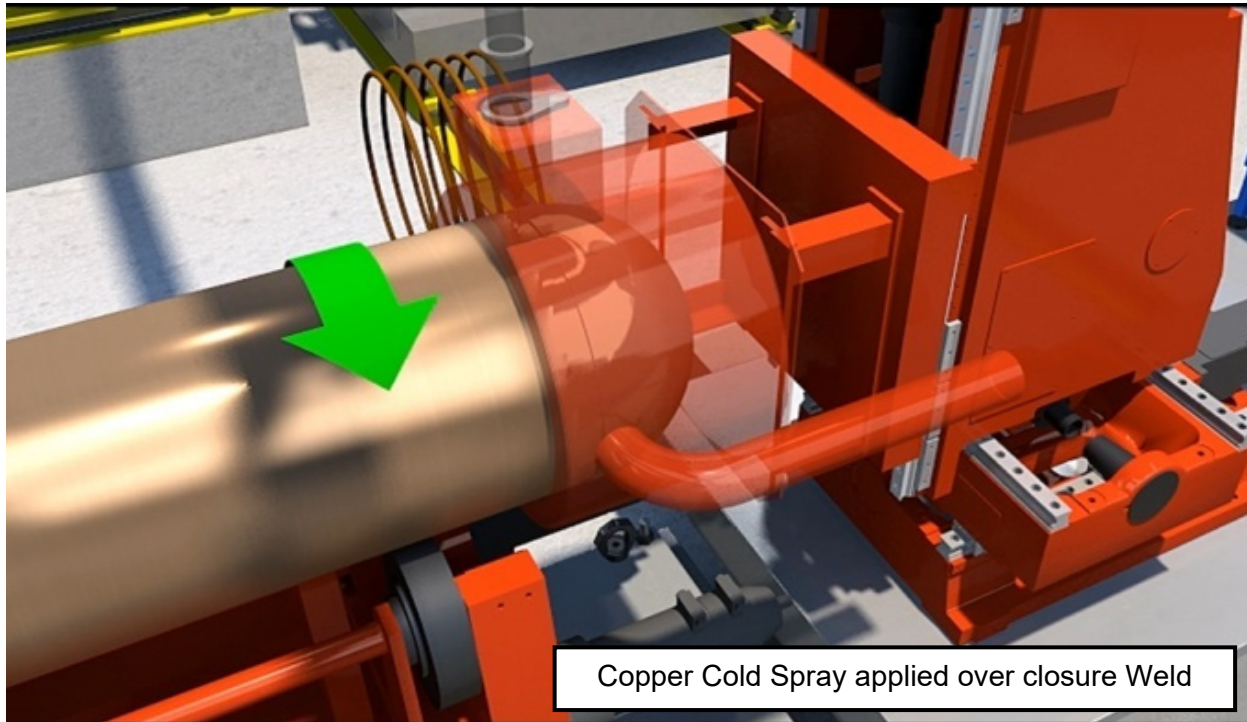


Figure 14: Copper Cold Spray Worktable

3.2.3.6 UFC Copper Annealing / Non-Destructive Examination Work Cell

When copper application and machining processes are complete, the UFC will enter one of four Copper Annealing / Non-Destructive Examination (NDE) work cells, where it will be transferred onto a rotary positioner.

Heat will be applied to the UFC at the copper annealing worktable, as shown in Figure 15, to soften the copper previously applied by cold spray to increase ductility.

Following copper annealing, the UFC will be transferred to the copper NDE worktable where the copper coating is inspected for defects using ultrasonic and eddy current NDE techniques.

When the copper NDE data is collected, the UFC will be placed back into a transfer cask and moved to the Transfer Cask Buffer area (i.e., waiting area) and held while the NDE data is reviewed and evaluated. The UFC assembly will be considered completed after confirming the copper coating meets the required acceptance criteria.

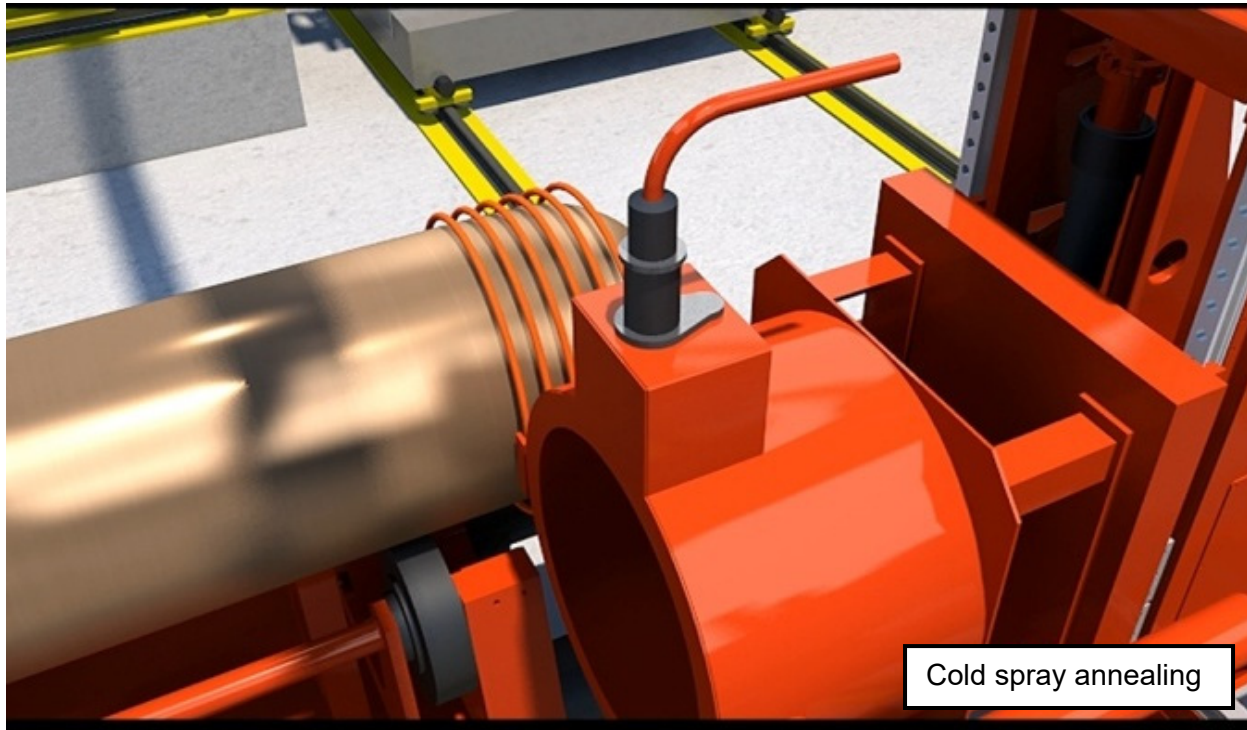


Figure 15: Copper Annealing Worktable

3.2.3.7 Buffer Box Storage, Handling & Dispatch Area

Upon positive confirmation of copper integrity by the NDE evaluation, the UFC will be transferred from the Transfer Cask Buffer area to the Buffer Box Storage, Handling & Dispatch Area, as shown in Figure 16. The main purpose here will be to assemble the Buffer Box, comprising two large Highly Compacted Bentonite (HCB) blocks with the UFC inside, as described in Appendix A. The area will also provide storage for unassembled HCB and fully assembled buffer boxes prior to dispatch to the underground. The storage will be environmentally controlled (humidity and temperature) to maintain the integrity of the bentonite clay prior to emplacement within the repository.

The Bentonite Buffer Box Storage, Handling & Dispatch area will receive the HCB blocks from the on-site Sealing Material Compaction Plant (SMCP). HCB blocks will be received on trucks and forklifted to a laydown area. Forklifts will then place the empty HCB blocks onto transfer trolleys that move them to the assembly area. The transfer trolley will enter the assembly area through an air control vestibule to be pre-staged for receipt of a completed UFC.

Completed UFCs will enter into one of two final survey cells where spot checks for contamination will be made. When it is confirmed that there is no surface contamination, the UFCs will be placed on trolleys and moved into the assembly area, where they will be placed into the lower HCB blocks. The top HCB block will then be set on top, and the fully assembled Buffer Box is then placed onto a conveyor system. They will be loaded into the UFC/Buffer Box Transfer Cask and transferred into the repository via the main shaft.

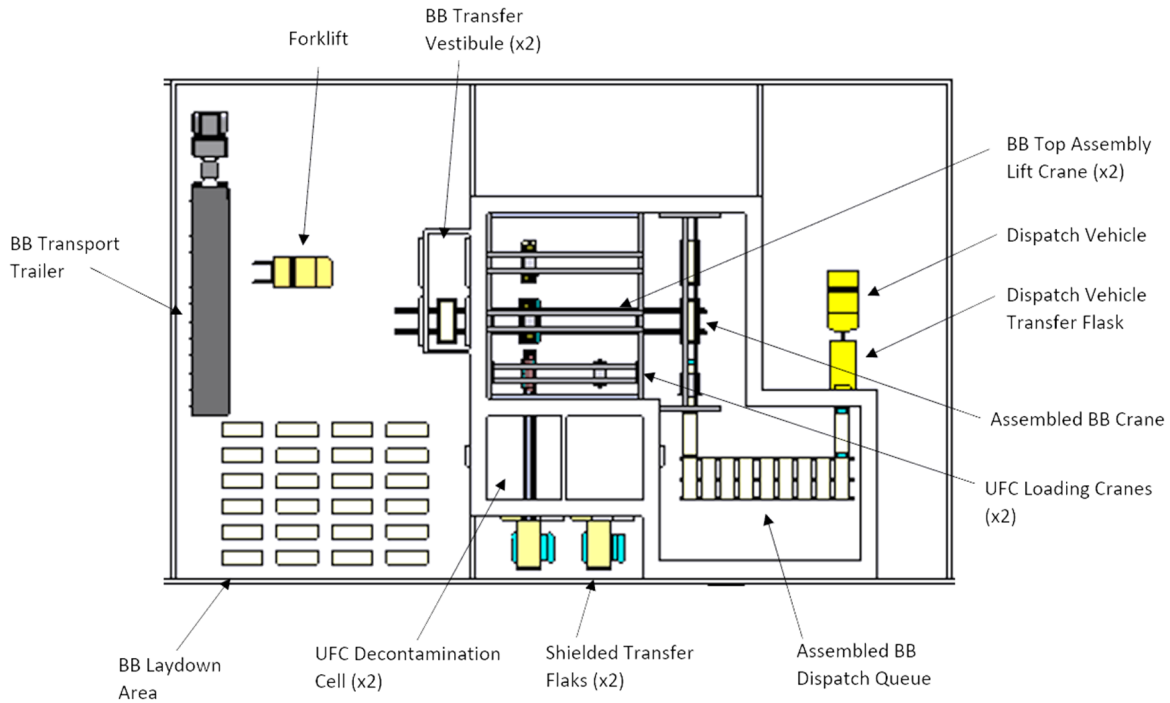


Figure 16: Bentonite Box Storage, Handling and Dispatch Area

3.2.4 Dispatch to Main Shaft

In the UFPP, the Buffer Box assembly will be inspected for loose contamination prior to its insertion into a UFC-buffer box transfer cask. The transfer cask will also be inspected for loose contamination prior to leaving the UFPP. If contamination is found, the equipment or buffer box assembly will be quarantined and decontaminated. The assessed buffer box transfer cask with UFC will travel through a dedicated travel route to the Main Shaft.

3.2.5 UFPP Contingency Cell

As part of the dedicated UFC processing systems, the UFPP will also be supported by several other auxiliary areas. These auxiliary areas will ensure safe operations at UFPP as well as safe emplacement underground in the DGR. One of these areas will be the Contingency Cell. The purpose of this cell will be to address UFC defects that have been discovered throughout the packaging process through the various visual and NDE inspections. These defects will be repaired independently from the regular processing line to minimize disruption to the main process. The contingency cell will house remote tooling that can make repairs above the capabilities of the main processing line, up to and including the ability to retrieve the used fuel from a UFC deemed unreparable. The UFPP design will permit transfer of a non-conforming UFC to this cell from anywhere within the UFPP. If the UFC is located on the non-CCA side they will be transferred to the CCA through the Decontamination Cell. Within the contingency cell, the following operations will be performed on an as needed basis:

- a) Weld defect removal;
- b) Weld repair;
- c) Removal of used fuel from UFCs that cannot be repaired; and
- d) Re-packaging used fuel into new UFCs and hemi-head installation.

UFCs from the Contingency Cell will be returned to the main process after the corrective actions have been undertaken.

3.2.6 UFC Intra-Plant Transfer System

The UFC intra-plant transfer system will be comprised of an AGV and shielded casks housing a UFC trolley, as shown in Figure 17 and Figure 18. The intra-plant transfer system only operates within the UFC Transfer Hall and will be responsible for transferring both empty and loaded UFCs between the different work areas.

The UFC Transfer Hall will be divided into the CCA area (before the UFC is sealed) and the non-CCA area (after the UFC is sealed). The areas will be separated by a barrier and can only be crossed through the UFC Decontamination Cells.

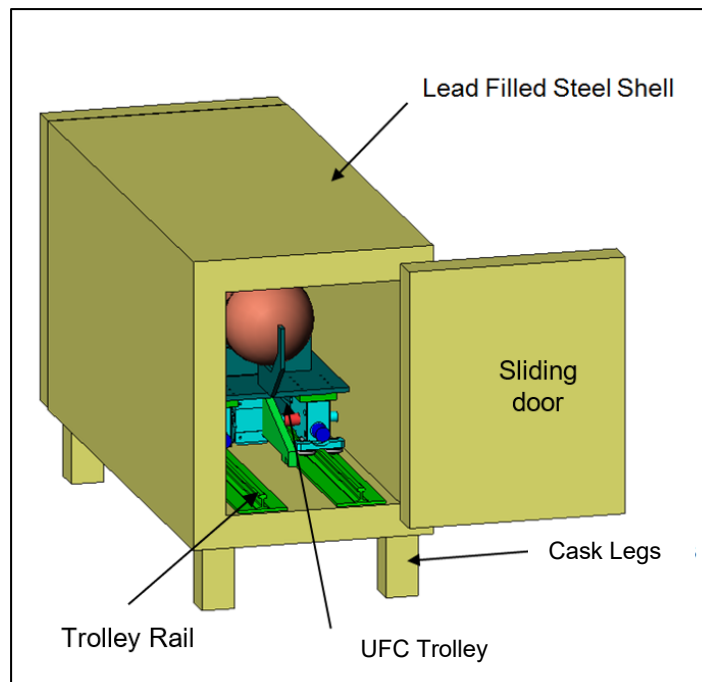


Figure 17: Shielded Used Fuel Container Transfer Cask concept

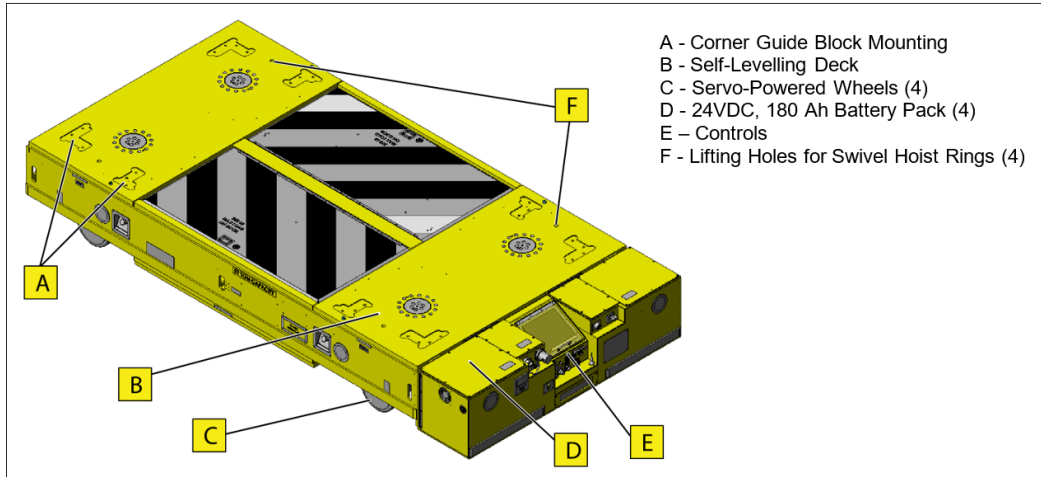


Figure 18: Automated Guided Vehicle (AGV) concept

3.2.7 UFPP Support Facilities

In addition to the main processing work cells, the UFPP will have several support systems necessary for facility operation. These include:

1. Operator Room, UFPP Control Centre – These are the main areas that will house the personnel responsible for plant operations and process monitoring inside the Transfer Hall.
2. Security Monitoring Room – This area will be used to house the main security monitoring systems and personnel.
3. Changeroom facilities and Washrooms – Changerooms will be for all personnel entering / exiting the UFPP from the Administrative Building. Washrooms will be provided within the changerrooms and throughout the facility (based on radiological zoning).
4. UFC Shipping / Receiving area – Empty UFCs will be received from outside the UFPP, inspected and dispatched into the Transfer Hall from this area.
5. Active Waste – Active waste generated during operations will be collected, sorted, segregated, and repackaged in this area.
6. Radioactive Materials Storage Area (RMSA)/Active Store – This area will be allocated for the laydown and storage of potentially contaminated tools and equipment from the packaging process.
7. General and Trolley Decontamination Rooms – These areas will support decontamination of tooling / equipment and AGVs / trolleys to support operations.
8. Active Maintenance Shop – This space will be allocated for performing maintenance and repair activities to equipment, including potentially contaminated equipment.
9. Warehouse – The warehouse will be used for receipt and storage of PPE, process consumables, equipment spare parts, etc.
10. Mechanical, Electrical, and Active Ventilation rooms – Housing the equipment in support of all UFPP operations (pumps, sumps, chillers, air handlers, filtration, heat exchangers, electrical panels, etc.)

3.3 AUXILIARY BUILDING Area P5

The Auxiliary Building will be situated adjacent to the border of the Protected Area and will provide facilities for surface operations staff who work primarily in the Protected Area. The building will be connected by covered walkways to the UFPP, the Service Shaft Complex, and the Administration Building.

The Auxiliary Building will be located as central as possible to the UFPP and Service Shaft to reduce the distance for personnel to walk, and to minimize the extent of needed covered walkways.

The Auxiliary Building will be a two-storey structure and will be equipped with full fire protection and radiation monitoring systems. The building will include the following facilities:

- Operational management areas consisting of offices and meeting rooms equipped with voice, video and data connections;
- A main control room from which staff will control and/or monitor the remote underground movements of the Buffer Box/UFCs;
- First Aid station;
- Change rooms, lockers, washrooms and shower facilities for staff and visitors accessing the Protected Area. Lockers will be in place to accommodate safety hats, boots, overalls and protective suits;
- Laundry facilities for all laundry needs exclusive to the Protected Area; and
- Protected Area cafeteria, which will be provided to minimize the movement of personnel into or out of the Protected Area during shifts. This cafeteria will be supported by the main cafeteria in the Administration Building, with foods being prepared and delivered on an as-required basis.

3.4 WASTE HANDLING FACILITIES Areas P6, P7, P8 & P9

This section addresses low and intermediate level waste (L&ILW) management facilities as well as those designed for management of non-radiological hazardous wastes. The principal subject waste streams, generated in both solid and liquid form, will be as follows:

- Low Level Waste (LLW): radioactive waste in which the concentration or quantity of radionuclides is above the clearance levels established by the regulatory body (CNSC), and which contains limited amounts of long-lived activity;
- Intermediate Level Waste (ILW): radioactive non-fuel waste, containing significant quantities of long-lived radionuclides and
- Free Release Waste: comprises waste that in which radionuclides are below CNSC clearance levels. This would include non-radioactive hazardous and non-hazardous materials.

3.4.1 Active Solid Wastes

Figure 19 illustrates the expected primary solid L&ILW streams. The main sources of active solid wastes are anticipated to be from the UFPP, the Auxiliary Building, and from the active liquid waste treatment processes.

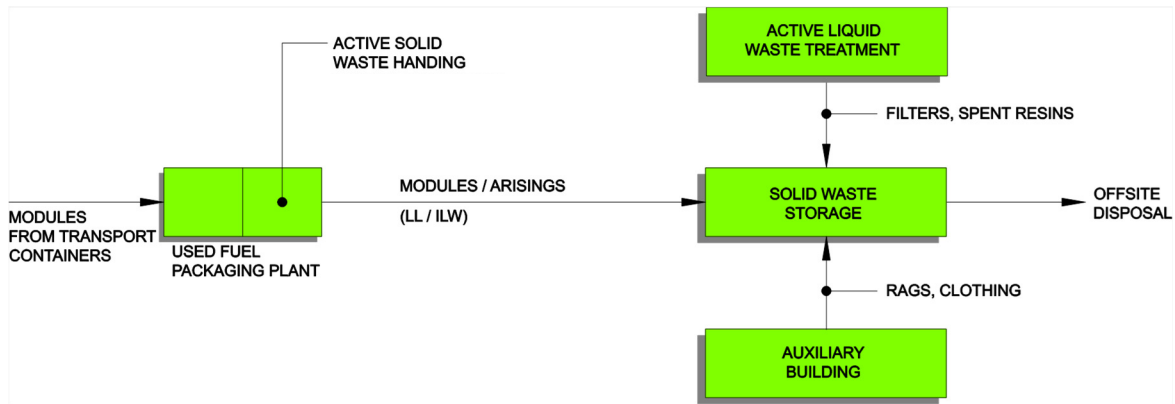


Figure 19: Active Solid Waste Flow Diagram

The modules and baskets from the incoming transportation packages (UFTPs and BTPs) will represent the most significant source of active solid waste. When a module/basket has been emptied of used fuel bundles, it will be processed including decontamination to achieve free-release limits to allow shipment to an offsite metals recycling facility. If decontamination to these levels is not achieved, it will be temporarily stored at an on-site interim storage building until sent off site for reuse at reactor facilities or for long term waste management.

Active waste streams will also include used HEPA filters from the active ventilation exhaust air units as well as spent filters and/or ion exchange media from the treatment of active liquid wastes.

Other active solid waste streams will include arisings (spent equipment/tools or components) from the maintenance of hot cell equipment. LLW streams will include waste generated from general decontamination activities and/or resulting from incidental contact with loose radioactive material such as cleaning materials and used personal protective equipment (PPE).

Table 4 identifies the quantities of solid L&ILW expected to be generated. After waste reduction, approximately 2,000 m³ of such wastes are anticipated each year. These processed wastes will be sent to an on-site interim storage building.

Table 4: Inventory of Active Solid Wastes

Source	Description	Level	Annual Quantity
UFPP	Modules from UFTPs	L or ILW	up to 330 m ³
UFPP	Baskets from BTPs	L or ILW	up to 40 m ³
UFPP	Arisings from operations and maintenance	ILW	3 m ³
		LLW	100 m ³
UFPP	Bead IX resins	L or ILW	500 L
UFPP	Powder resins	L or ILW	120 kg
UFPP	HEPA & cartridge filters	L or ILW	285 filters
UFPP	Hot Cell vacuum filters	L or ILW	0.5 m ³
Active Ventilation Exhausts	Used HEPA filters	LLW	TBD
Aux. Building & other Facilities	Dry swabs, swipes and clothes, etc.	LLW	TBD
	PPE (clothing, gloves, etc.)	LLW	10,000 kg
Active Liquid Treatment	Spent filters and IX media	L or ILW	20 m ³
Various	Miscellaneous	L or ILW	10,000 kg

3.4.2 Active Liquid Wastes

Figure 20 identifies the expected liquid L&ILW streams. Similar to the active solid waste flows, the primary sources are anticipated to be from the UFPP and Auxiliary Building.

Active liquid waste flows from the UFPP will originate from the decontamination of used fuel modules, baskets, cell washdowns, and from the decontamination of transportation packages and containers. The other primary source of liquid waste flows will include some laundry wash and rinse waters (normally directed to sewage treatment system, only rerouted if indicated by monitoring).

Table 5 identifies all sources and the associated quantities of liquid L&ILW that is expected to be generated. In total, approximately 200 m³ of containerized active liquids and 9,000 m³ of piped active liquid wastes will be produced each year.

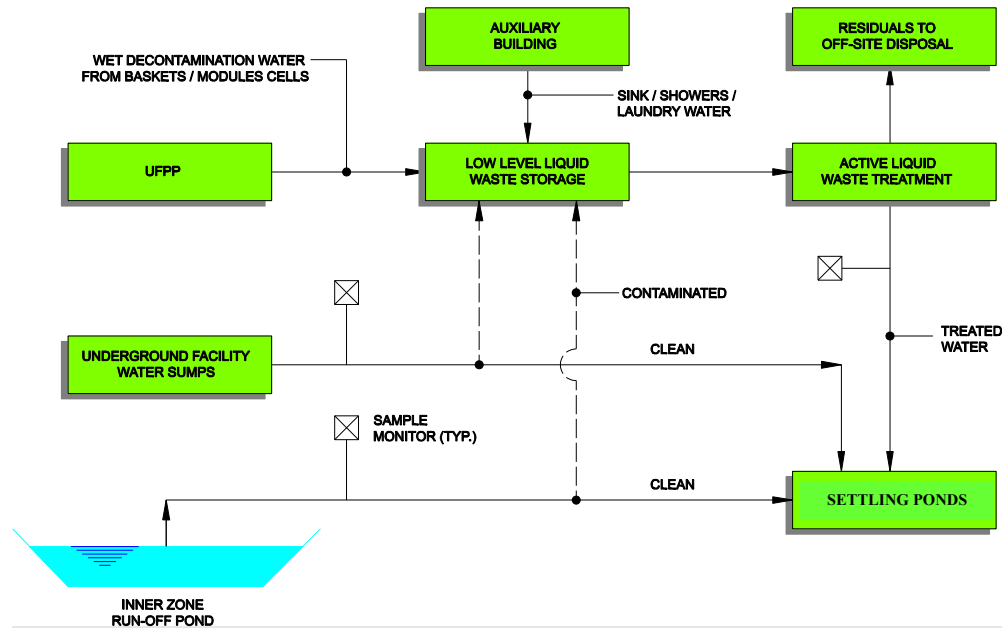


Figure 20: Active Liquid Waste Flow Diagram

The discharge water from the mine dewatering settling pond (“Underground Facility Water Sumps” in Figure 20 which is Area P17 in Figure 4) and the storm water management pond (“Inner Zone Run-off Pond” in Figure 20 which is Area P10 in Figure 4) are normally expected to have radioactivity concentrations well below limits that are acceptable for release to an off-site water body. However, in the remote event that the monitoring of pond discharge water finds radioactivity levels to be above acceptable limits, then the pond water would be routed to active liquid waste treatment building for treatment. The water could be taken to the treatment building by tanker truck or a pumping system (to be determined in the detailed design phase).

Table 5: Inventory of Active Liquid Wastes

Source	Description	Level	Annual Quantity
UFPP	Module / basket decontamination	ILW	1,250 m ³ (piped)
UFPP	Active cell wash downs	ILW	10 m ³
UFPP	Transportation package / container decontamination	ILW	1,600 m ³ (piped)
Lab. & Test Areas	Cleaning and samples	LLW	100 m ³
Auxiliary Building	Laundry, change rooms	LLW	max. 6,000 m ³ (piped)
Waste Management Area	Cleaning of package exteriors	LLW	25 m ³
Underground or Surface	Mine Dewatering Settling Pond (P17) & Storm Water Management Pond (P10)	LLW	normally clean and nil (piped)
Active Liquid Waste Treatment	Spent regenerates	LLW	30 m ³ - 60 m ³

3.4.3 Non-Radiological Hazardous Waste

Various non-radiological, hazardous solid and liquid wastes are also expected to be generated from the on-going operation and construction activities at the DGR site. These will include:

- Solvents used in decontamination and cleaning in non-radiological areas;
- Lubricants and greases;
- Petroleum based fuels; and
- Explosive residues.

To minimize the total amount of these waste materials, steps will be taken to limit activities that generate these wastes, find less-hazardous replacement materials, and ensure separation of incompatible materials such as organic solvents and inorganic acids. All conventional waste materials will be collected and sent to a disposal facility that is licensed to accept these types of waste materials. Spill containment and monitoring will be provided wherever hazardous liquid wastes are handled and stored.

3.4.4 Non-Radiological Non-hazardous Waste

There will be a number of conventional waste streams generated at the DGR (e.g., office and lunchroom waste, etc.). To the extent possible, the quantity of these wastes will be minimized and segregated by type for recycling and organic composting.

3.4.5 Waste Management Approaches

With respect to the waste facilities, four separate operations will be incorporated into the design and operation of the DGR. As discussed in the following sections, these will include:

- Active Solid Waste Handling Facility – meant to receive active solid wastes from the UFPP;
- Waste Management Area – which will manage active solid waste materials;
- Low-Level Liquid Waste Storage Area – which will receive low-level liquid waste materials prior to transfer to the treatment area; and
- Active Liquid Waste Treatment Area – a processing plant for active liquid waste materials.

Generally, non-hazardous and non-radiological refuse will be handled as in any other type of industrial setting. Such garbage will be directed to a local municipal landfill or other waste management facility. The approach to handling non-radiological hazardous waste is expected to be similar, with wastes being transported off-site to an appropriate hazardous waste management facility. The quantity of such materials will be reduced to the maximum extent possible, and any collected wastes will be shipped off-site for recycling or long-term management.

Active Solid Waste Management Systems (Areas P6 & P7)

L&ILW management activities will center on two on-site operations, the active solid waste handling facility, and the waste management area (Areas P6 and P7 in Figure 4, respectively).

The active solid waste handling facility will be associated with and attached to the UFPP and will serve as a staging area for solid wastes from that building. It will comprise an area for managing of modules/baskets and for processing of other solid wastes materials. Once processed and packaged, the containerized wastes will be directed to the waste management area.

The waste management area will incorporate a stand-alone storage building. The wastes will be stored in suitable containers to prevent damage and loss of containment. A compactor to consolidate collected material will be provided.

It is currently assumed that active solid wastes which are not, or cannot be, decontaminated to free-release limits will be placed into suitable transportation containers and shipped off-site to a licensed long-term management facility. As the quantity of waste which is combustible is expected to be limited, on-site incineration for volume reduction will not be pursued. However, further treatment at off-site facilities may be considered where appropriate.

Active Liquid Waste Management Systems (Areas P8 & P9)

Active liquid waste treatment will be managed through two facilities, a storage building located in the low-level liquid waste storage area (Area P9 in Figure 4), and the active liquid waste treatment building (Area P8 in Figure 4), where the latter is a processing plant for the liquid wastes.

The storage building, incorporating secondary containment for spills or leaks, will provide for the interim assembly of collected liquids prior to treatment. The building will house storage tanks to receive piped and containerized active liquids as well as an area where containerized liquids would be stored. One tank will be kept empty to provide space for unplanned receipts. Over normal operations, active liquids will be transferred into one of the storage tanks for blending or moved directly to the treatment building.

The active liquid waste treatment building will house the following equipment:

- Two feed / equalization tanks with feed pumps;
- Two treated water collection and monitoring tanks with transfer pumps;
- Treatment systems comprising filtration to remove particulate contaminants, ion exchange or membrane separation to extract dissolved contaminants and possibly post-treatment filters to allow for recycling of the treated water;
- Three tanks to supply regeneration / cleaning liquids and receive spent regenerant / wash water and concentrate from the membrane separation modules; and
- Pumps to serve the three tanks above.

The treatment of active liquid wastes using particulate filters and ion exchange columns is commonly used in the industry wide including nuclear power plant operation. The system will be comprised of three 50% capacity modules, two of which would be operating at any given time with the third unit on stand-by. Alternatives to this treatment approach include the use of membrane separation technologies such as ultra-filtration and reverse osmosis.

3.5 SWITCHYARD, TRANSFORMER AREA AND EMERGENCY GENERATOR BUILDING Areas P11, P12 & P13

Regular electrical power and emergency electrical power will be supplied by the switchyard, transformer area and emergency generator building. For security, these facilities are all located in the Protected Area.

3.5.1 Switchyard

The switchyard (Area P11 in Figure 4) is designated to host all high voltage equipment for circuit-breaking interruption, circuit-making, isolating disconnects, switching, and for the protection of transformers, lines, cables, and capacitor banks. All designated equipment mechanisms will be fully enclosed and protected. Protection from high winds, rain, sleet and snow will be in place. The switchyard area will be surrounded by a dyke (or perimeter ditch and sump) to collect any accidentally spilled transformer oil. It will be lined, as required, and have a surface comprising a compacted granular sub-base.

3.5.2 Transformer Area

Two step-down transformers capable of handling the required electrical load will be located at the sub-station (transformer area) with all controls and switchgear housed in an adjacent building. These facilities are identified as Area P12 in Figure 4.

Table 6: Site Power Requirements

Equipment Description	Net M.V. Run Demand		Net L.V. Run Demand	
	(kW)	(kVA)	(kW)	(kVA)
Used Fuel Packing Plant			6,438	8,048
Sealing Materials Operations			7,910	9,224
3 Shafts Substations & Hoists	1,336	1,498	614	747
Ventilation Systems including Exhaust Vent Shaft Substation and Ventilation Shaft Complex	933	1,085	2,660	3,246
Waste Management Operations			355	444
Underground Operations			2,701	3,291
Other Underground Operations and Surface Facilities	1,193	1,476	1,981	2,410
Total	3,462	4,059	22,659	27,409
Total demand, M.V. + L.V. excluding contingencies (values rounded)			26,100 kW	
			31,500 kVA	
Allowance #1: * Defined load but not quantified Load: Load that exists but whose kW rating has not been defined (5% of total defined load).			1,306 kW and 1,573 kVA	
Allowance #2: Electrical Losses, kW (3% of total defined load)			784 kW and 944 kVA	
Allowance #3: Unknown Load/Miscellaneous Loads (2% of total defined load) (rounded)			522 kW and 629 kVA	
Total Site Power Demand Including 10% (allowances# 1, 2, and 3) Defined Load (values rounded)			28,700 kW	
			34,600 kVA	

Notes: M.V. (4,160 volts and 13,800 volts) and L.V. (600 volts) means medium and low voltage, respectively.

* For a Pre-feasibility Load List, an estimate of the electrical requirements for certain (typically small) loads are not completed individually. Instead, an allowance factor of 5% is applied to of the total known load.

The total electrical power demand for the facility is indicated in Table 6. The site's power supply will be received from a high voltage overhead line branching off from the regional power grid. This line is expected to be tower mounted, with towers generally spaced at approximately 200 m intervals (pending voltage system and tower design) for stability.

After being received at the two transformers, the electrical power will be conveyed via overhead medium voltage (13.8 kV) power lines to the facility distribution level. The power lines will run alongside access roads within the surface facilities to all buildings and terminate at step-down units. Step-down transformer units will provide the needed power for motors, buildings, compressors and other electric driven installation as per requirements. Use of underground lines with armoured cable will be considered where required depending on site conditions.

The transformer area will be situated within the previously described switchyard. Reinforced concrete platforms will be provided for the transformer units with mounted switches in steel box enclosures designed with suitable fire wall separation and fire protection measures.

3.5.3 Emergency Generators

The emergency generator building (Area P13 in Figure 4) will house the emergency power generators and related equipment. The location and design of the emergency generator building will take into account the flood hazards, as identified in NWMO (2016), to ensure continued operation under such conditions. Three diesel generators (one for standby) will be able to provide the emergency power needed at the DGR facility. In this respect, the primary loads that would be served by the emergency generators are for the underground ventilation system as well as for the Exhaust Ventilation Shaft hoist and the Service Shaft auxiliary hoist. As illustrated in Table 7, allowances have also been made to sustain critical services in the UFPP, and the various other surface and underground operations.

Table 7: Estimated Emergency Power Requirements

Applicable Emergency Services	Needed Power (kW)
UFPP Area	1,960
Shaft Complexes and Ventilation Systems	2,040
Surface Buildings & Security Control Systems	1,470
Miscellaneous Underground Requirements including Pumps	210
Miscellaneous Surface Requirements	430
Defined but not quantified load allowance (approximately 5%)	310
Unknown/Misc. Loads (approximately 2%)	120
Electrical Losses (approximately 3%)	180
Total:	6,720

The 4.16 kV diesel generators will be connected to 4.16 kV generator switchgear. The generator switchgear will be connected to the plant main 13.8 kV switchgear through 4.16/13.8kV step-up transformers. Plant main 13.8 kV switchgear will distribute power to different areas through 13.8 kV power line. Each area equipment would have 13.8/4.16 step-down transformer to feed 4.16 kV loads, and 4.16/0.6 kV power distribution transformer to feed 600V. That is, the switchgear will be compatible for either grid power or diesel generated power. All other controls and switches will be housed in the emergency generator building and be capable of switch-over from the main grid to the diesel generators. A separate storage room for diesel tanks (2 weeks supply) and oil will be provided in the building.

Most buildings at the DGR will have connections for emergency power to the key areas, corridors, washrooms and external security lighting, key offices, laboratories and essential services. In an emergency, all security lighting and facilities for monitoring and detection of intrusions will receive full power.

In addition to the emergency generators, uninterrupted power supplies (e.g., battery back-up) will be in place in various facilities to ensure the continued functioning of vital computer, instrumentation, and security equipment.

3.6 QUALITY CONTROL OFFICES AND LABORATORY Area P14

The quality control office and laboratory facility (Area P14 in Figure 4) will provide space for resident quality control specialists and scientists. The staff will provide quality control, monitoring and testing for such items as groundwater, stormwater, air quality, and radiation-related issues.

The building, envisaged as a single storey structure, will be located in the Protected Area. It will house the quality control offices, laboratories and workstations for the facility's technicians, researchers, quality inspectors, scientists and managers. Work benches, experimental areas and refrigerators (for any chemicals or reagents requiring cool storage conditions) powered by emergency power will be in place. Meeting rooms will be provided.

In addition to the normal sprinkler system in the ceilings, firefighting equipment will be installed near most work areas and outside the laboratories.

3.7 ADMINISTRATION BUILDING INCLUDING FIREHALL AND CAFETERIA Area B2

The Administration Building (Area B2 on Figure 4) will be the first building that visitors and most staff encounter when coming to the DGR facility. Equipped with full fire protection and monitoring systems, the building will be divided into three main areas: the administrative offices, a cafeteria and the firehall. It is estimated that up to 700 full-time staff will be working at the DGR facility and approximately 200 staff will have office space in this two-storey structure.

Employees will enter through the parking area adjacent to the building and proceed to their respective locker spaces or to the Auxiliary Building. Protective clothing (for those working inside the Protected Area) and civilian clothing will be stored in separate lockers. The lockers will be of sufficient size to accommodate safety hats, boots and overalls. Provision will be made for locker space for site visitors including inspectors and government officials. Showers will also be in place.

The cafeteria will provide sit-down areas with a serviced hot kitchen for continuous full meal services.

The firehall (supported by the security monitoring room) will be equipped with detection and monitoring equipment for any fire hazards or smoke from any of the DGR facility operations. Firefighters will be on duty each shift, with other fire team members on standby in the event of an emergency. Two large municipal fire trucks will be available with telescopic ladders, hoses, pumps and all other typical fire-fighting tools.

The main administrative area will have offices for senior management and key staff, boardrooms for meetings and training sessions, and cubicles for other supervisory or technical personnel. Offices will have full internal and external communications facilities, as required, including internet, telephone, two-way radio systems and wired networks. Additional facilities at the Administration Building will include:

- Transportation and logistics coordination centre equipped with display monitors for the real time tracking of used fuel transport trucks;
- Procurement area to serve as the central procurement department for all on-site equipment and consumables;
- IT and communication facilities;
- Health and safety training room and offices to be used for the training of employees and the orientation of visitors to the DGR; and
- Nursing station and first aid area with consultation rooms and a doctor's office. A full-time nurse practitioner will be on duty for all shifts.

3.8 SEALING MATERIALS PRODUCTION FACILITIES

Areas B3, B6 & B13

The sealing material receipt, storage and preparation facilities will be used to produce various concrete and clay-based sealing materials for the encapsulation of the UFCs / buffer boxes in the underground repository. The facilities will comprise of a concrete batch plant (Area B13 in Figure 4) and a Sealing Material Compaction Plant (SMCP) with associated material storage bins (Areas B6 and B3, respectively). Materials, quantities or processes related to the backfilling and closure of access tunnels, shafts or other openings would be addressed at the time of final facility decommissioning and closure.

From the concrete batch plant, a Low Heat High Performance (LHHP) concrete mix will be produced for constructing bulkheads at the entrance to each placement room. Concrete will be required for the access tunnel floors. During the operations phase, the SMCP will produce the following clay-based sealing material products:

- Highly compacted bentonite (HCB) blocks for use in the buffer boxes;
- HCB blocks for spacers between the buffer boxes, floor tablets, and for the room seals; and
- GFM for filling the space between the stack of buffer boxes and spacer blocks and the surrounding rock.

Aggregate products will be stockpiled and stored within the concrete batch plant area. Overhead field conveyors will be used to bring finished aggregate product to the concrete batch plant. In all, the aggregate, concrete batch and SMCP operations are seen as an interconnected network.

The sealing materials production facilities will be situated adjacent to the Protected Area, so as to be located as close as possible to the Service Shaft and UFPP. This location will minimize the distance materials will need to be conveyed, help to reduce the footprint of the site, and lessen the need for workers in the SMCP to enter the Protected Area. The products will be either brought to the UFPP for the buffer box assemblies or to the Service Shaft for delivery underground.

For day-to-day operations, the concrete batch plant will run on an as-needed basis. Conversely, the high demand for clay-based sealing materials will necessitate a three shift, daily operation for the SMCP. All required materials (modified granular A, different binders such as cement T50, silica fume and silica flour, as well as bentonite and other clays) will be sourced from external suppliers.

The main difference between the crystalline and sedimentary repository options is the spacing between adjacent buffer boxes. This means that there will be a difference in the HCB spacer block size, which will result in variances in the quantities of the fill materials that will be required.

The following sections initially describe the material requirements for the concrete batch plant and the SMCP. Detailed descriptions of each plant are provided thereafter.

3.8.1 Material Requirements for Concrete Batch and Sealing Materials Compaction Plant

Table 8 summarizes the approximate raw materials required at the concrete batch plant and SMCP on an annual basis. Where there is a difference, separate values are provided for the crystalline and sedimentary design cases.

Table 8: Materials Requirements for Concrete Batch and SMCP

Material	Concrete Batch Plant (tonnes/year)		SMCP (tonnes/year)	
	Crystalline	Sedimentary	Crystalline	Sedimentary
Concrete Stone	985	836	N/A	N/A
Concrete Sand	1132	930	N/A	N/A
Cement T50	502	382	N/A	N/A
Silica Fume	23	27	N/A	N/A
Silica Flour	47	54	N/A	N/A
Superplasticizer	32	25	N/A	N/A
Bentonite*	N/A	N/A	29,000	39,000
Water	222	174	N/A	N/A
Total	2,943	2,428	29,000	39,000

Note: *Bentonite mass reflective of final as-place condition, as bentonite trimmed during shaping will be recycled as GFM

3.8.2 Concrete Material Requirements

Low Heat High Performance (LHHP) concrete will be used for the construction of the floor smoothing layer and the placement room bulkheads immediately adjacent to room seals (Figure 51). As a result, the demand for LHHP concrete is relatively low on a week-to-week basis. However, the plant does need to operate year-round. The other mixes, such as shotcrete, grout or other concrete uses would also place a demand on plant operations. The LHHP concrete materials produced will be highly specialized, and the binders will require extensive on-site testing prior to use.

3.8.3 Clay-Based Sealing Material Requirements

Clay-based sealing material will be required for the buffer boxes as well as for preparing and filling the placement rooms. The material composition of each of these clay-based sealing materials is as follows:

- Highly Compacted Bentonite (HCB) – 100% bentonite
- Gap Fill Material (GFM) – 100% bentonite

On an average work week basis (and allowing for a 10% rejection rate), the following materials are expected to be produced:

- 125 HCB buffer blocks for buffer boxes and dummy blocks (approximately 1 m x 0.5 m x 2.9 m);
- 65 HCB spacer blocks; (approximately 1 m x 2.9 m x either 0.3 m or 0.7 m)
- HCB floor tablets (0.15 m thick) for underlying both spacer blocks and buffer boxes;
- HCB forklift hole bricks for the placement of the Spacer Blocks or Buffer Blocks (approximately 0.5 m x 0.14 m); and
- granular GFM for filling remaining voids (roughly 140 and 185 tonnes for the Ignace and South Bruce DGRs, respectively).

Figure 21 illustrates a cross-section view of the placement room for the crystalline DGR design concept and the arrangement of UFCs/buffer boxes, spacer blocks and gap fill. The spacer blocks in the placement room will be approximately 1 m in height and 2.9 m in length. The spacer block thicknesses are 0.3 m and 0.7 m for the crystalline and sedimentary DGR design concepts, respectively.

Storage silos will inventory approximately two weeks of raw product.

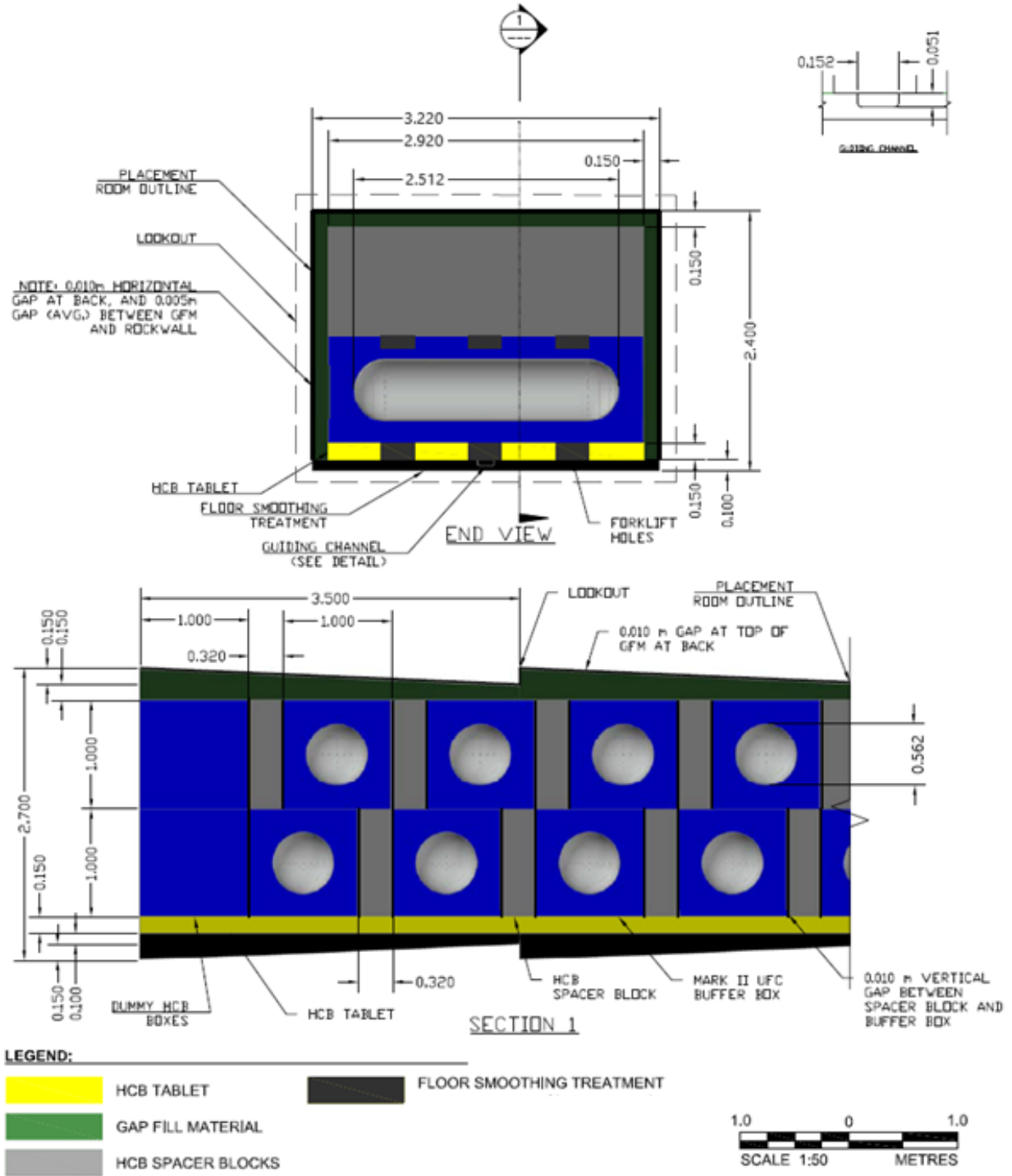


Figure 21: APM Sealing Material in Placement Room Section View (Crystalline Geosphere)

3.8.4 Aggregate Supply

The minimal requirement for aggregate does not support the establishment of an on-site aggregate plant. Instead, it is assumed that this material (associated with the production of LHP concrete), will be purchased and delivered from an external source. In addition, an annual aggregate supply of Granular A of about 400 and 500 tonnes for the sedimentary and crystalline sites, respectively, and Granular B of about 800 and 1000 tonnes for the sedimentary and crystalline sites, respectively will also be required for the granular base underlying the concrete floor for the development of the tunnels.

3.8.5 Concrete Batch Plant Description

As shown in Figure 22, the concrete batch plant (designed to primarily produce LHP concrete) will be fed by a loader bringing aggregate from storage to a twin (coarse/fine) feed bin. The aggregate will be delivered to a batcher where it will be weighed and dispensed into a ready-mix truck. The cement T50, silica fume and silica flour will be delivered from an external resource via tanker trucks directly to the plant (Area B13 in Figure 4).

Cement T50 and silica fume will be stored in 75-tonne silos, with silica flour kept in a 150-tonne silo. These storage capacities are considered to be sufficient to supply LHP concrete for two successive bulkhead pouring campaigns. The binders will be subsequently dispensed into a cement batcher, where they are weighed and discharged into a ready-mix truck (along with water and admixture). At the ready-mix truck, a homogeneous product is formed which is then delivered to the Service Shaft where it would be delivered underground via a slickline and then by underground ready-mix trucks to the pour location. The concrete plant will be enclosed where necessary to allow for year-round operation (to minimize winter weather impacts).

The plant will produce material constantly during the LHP concrete bulkhead pours with a required capacity of between 9 m³/hr and 18 m³/hr. A small, commercial concrete batch plant in the operating range of 20 to 25 m³/hr is considered suitable for this application.

A crew that is dedicated to the concrete batch plant on a full-time basis would not be necessary because the plant would only be used periodically to produce concrete for the room bulkheads, placement room floors, and panel access tunnel floors. Operations to produce concrete material will consist of a trained team (likely a supervisor, loader operator, ready mix truck drivers and batch plant operator) gathered from other parts of the DGR facility operations team.

Each year, up to eight bulkheads pouring campaigns are anticipated. Each bulkhead pour will take about 50 m³ of LHP concrete. Two ready-mix trucks will provide enough surface delivery capacity. As binder and aggregate materials are confirmed to meet target specifications, they will be used in the concrete batch plant. Slump and air content will be measured for each load prior to placement.

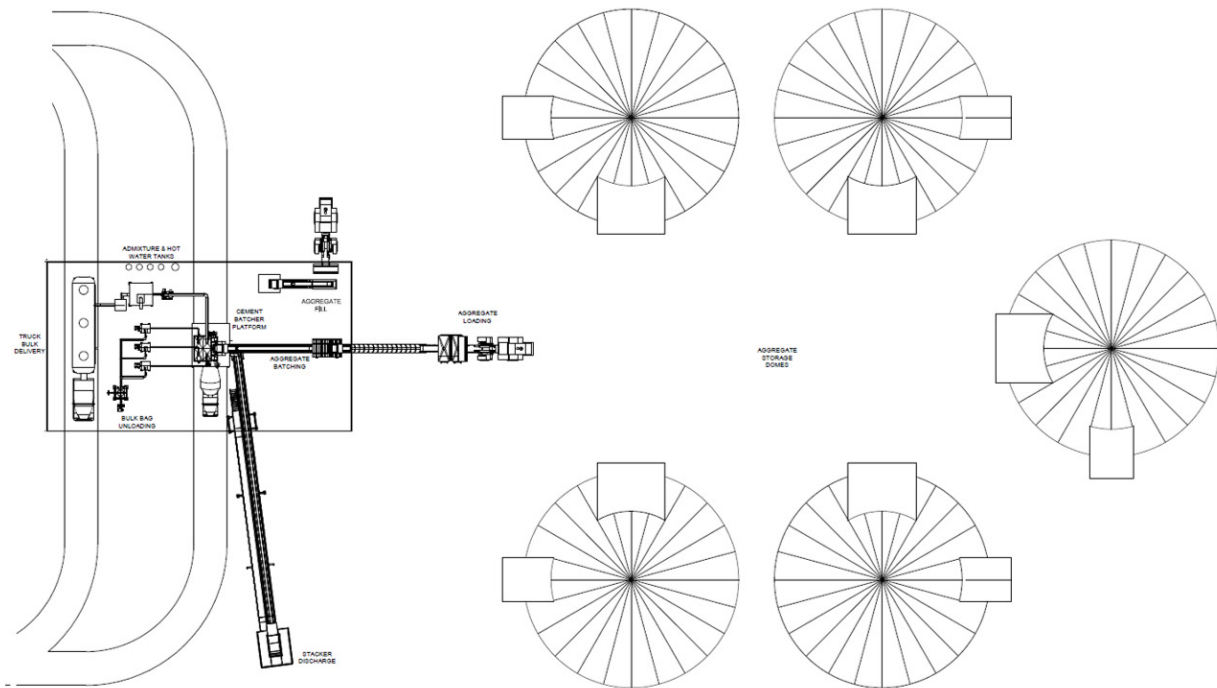


Figure 22: Conceptual Aggregate Storage and Concrete Batch Plant Layout

3.8.6 Sealing Material Compaction Plant (SMCP) Description

The SMCP will produce HCB spacer blocks, HCB floor tablets, HCB blocks for the buffer box, and Gap Fill Material (GFM) for filling void spaces between the buffer boxes and spacer blocks, floor tablets, and the surrounding rock. The spacer blocks, floor tablets and bentonite GFM will be delivered from the SMCP to the Service Shaft inside the protected area via security gate for transfer underground. The HCB components, used for the Buffer Box assembly, will be directed to the UFPP. The SMCP is divided into two primary sections:

- Raw materials storage, handling, and mixing; and
- HCB block, HCB spacer block, HCB floor tablets and GFM production.

Bentonite will be delivered via tanker trucks to the plant. Ten exterior silos, each of a 150-tonne capacity, will be in place to dispense bentonite using rotary valves, day bins and positive displacement blowers. Water will be subsequently added to the mixer to produce a homogenous material after blending for the HCB Blocks. The bentonite storage silos will accommodate the equivalent of approximately two weeks of material consumption.

Blended gap fill will be discharged from the batch mixers to a briquetting circuit operating under negative pressure to reduce the infiltration of dust to the surroundings. The material will be loaded into tanks on rubber-tired trolleys for transportation to the underground repository or storage.

The presses that will produce the buffer box, floor tablet, and spacer block materials will be specialized items designed to suit this purpose (Johansson, 1999; Koskinen, 2012). They will be hydraulically driven units with custom fabricated moulds. A depiction of the type of press envisioned for the production of these clay-based blocks is shown in Figure 23.



Figure 23: Example of Closed-Die Compaction Press

Figure 24 shows an example of a small portable press that produces blocks through uniaxial, two-sided compression. This device has been demonstrated as being capable of producing small blocks of highly compacted bentonite at a very high rate.



Figure 24: Portable Uniaxial Highly Compacted Bentonite (HCB) Brick Maker

Based on initial estimates about 110 to 160 hours of compaction machine time will be required to produce HCB segments to fulfil 1 week demand. Additionally, spacer blocks would require an estimated 35 to 50 hours of pressing time per week, depending on the size of block ultimately produced. The target minimum dry density for the HCB blocks is 1.7 g/cm^3 .

Cold Isostatic Press (CIP) technology that could produce the buffer and spacer block materials are also being considered (Ritola and Pyy, 2011). A depiction of the type of press envisioned to produce these clay-based blocks is shown in Figure 25.

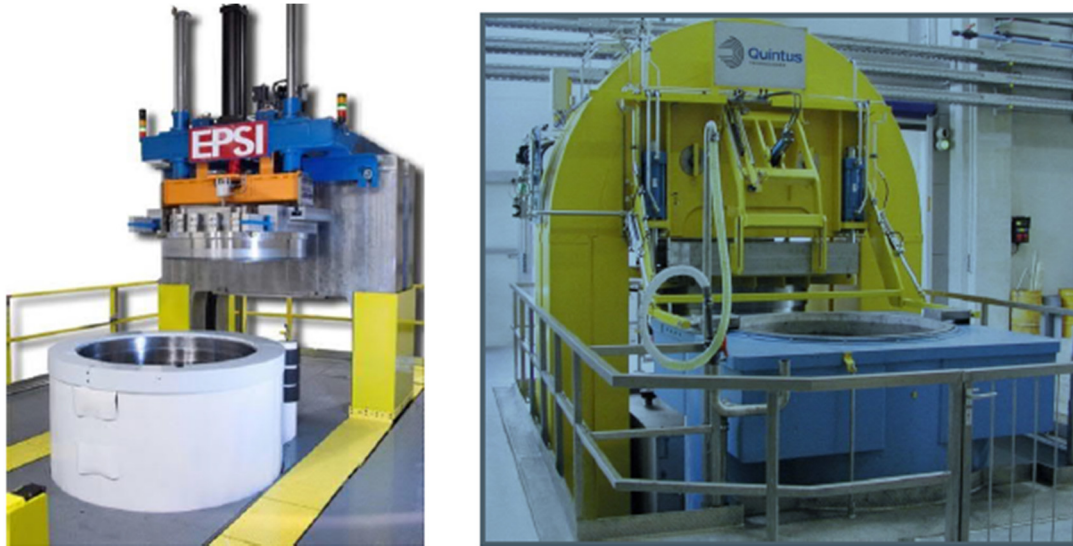


Figure 25: Examples of Commercially Available Cold Isostatic Press, Manufactured by EPSI (Left) and Quintus (Right)

Specially designed equipment will be used to lift the HCB products out of the moulds. A prototype vacuum lift system for handling HCB blocks is shown in Figure 26. This lifting technique is non-intrusive, safe, and effective way to handle these types of compacted materials.



Figure 26: Prototype Buffer Block Vacuum Lift

The SMCP will be a highly automated facility, operated by a small number of skilled workers on the plant floor. Such workers are likely to include a plant supervisor and foreman, control room and floor operators, and quality control technicians.

The SMCP and its compacted or granulated materials' storage areas will be enclosed to maintain climate and humidity control (to minimize moisture absorption and ensure the integrity of the finished products). The exterior silos or storage domes will also have heated concrete floors (as required) to protect stockpiles from freezing. The enclosed structures will further help to prevent wind erosion effects that can cause fugitive dust emissions. A multi-chamber dust collection baghouse will be in place to collect any dust generated by the sealing materials operations.

A quality control laboratory and geotechnical technicians will be housed in the SMCP. The laboratory will be responsible for materials testing of the imported aggregate and clay materials, as well as for testing of the products from the concrete batch plant and SMCP.

3.9 GARAGE / WAREHOUSE / HAZARDOUS MATERIALS STORAGE

Areas B5 & B7

The garage / warehouse / hazardous materials storage areas will be housed in a one-storey building and it will include maintenance shops, repair bays and a space allocated for hazardous materials storage.

The building will be a single structure with partition walls between the distinct areas, and a limited-access area for hazardous materials storage. The garage area and one portion of the storage warehouse will be heated while another section of the warehouse will be unheated. While separate entrances will be provided for the garage and warehouse areas, a wide opening sliding double-door will be provided for off-loading supplies in the main warehouse through the garage. Firefighting equipment will be available in all rooms. Additional details are as follows:

- Maintenance and repair bays – the garage area will have three vehicle maintenance bays as well as benches and extra space for machining, welding, etc. While major vehicle and equipment repairs will generally not be handled at the DGR (instead being carried out at designated and proximate authorized facilities), the maintenance and repair bays will be available to deal with emergency and routine requirements.

The maintenance and repair area will be equipped with all the tools and small machinery needed including hydraulic jacks, ramps and lifts as well as an overhead crane. An air compressor will be supplied for pneumatic tools and equipment and stored lubricants will be available for routine maintenance;

- Truck wash bay – a single bay will be provided for washing buses, trucks and other equipment. Discharged water will collect in a holding pond where suspended particles will be allowed to settle out. A separator in the pond area will collect oils for containment and removal before the wastewater is re-used or discharged to the environment. The collected water will be topped up with fresh water as required; and
- Warehouse – a warehouse area, with forklifts, will be provided for the bulk storage of all equipment, parts and items required for the areas of the DGR facility without their own

storage. This warehouse will also be used as a staging area for distribution to other buildings. Warehouse space will be split as further described below:

- An unheated area for storing bulky items (not associated with used nuclear fuel waste) at the far end of the building;
- A heated storage area for mechanical and electrical equipment, spare parts, workshop items, benches, jacks and toolkits;
- A heated area for construction related items including cement, geotextile membranes, pipes, couplings, etc.; and
- A separate and limited-access (fenced-off) heated area for hazardous materials storage including any reagents for water or wastewater treatment, laboratories, etc.

3.10 WATER STORAGE, TREATMENT AND DISTRIBUTION

Areas B10, B11 & B12

Service (raw) water for the DGR facility will be sourced from a local river, water body, or well.

The required average water supply rate or water demand for the surface facilities during operations is expected to be approximately 97–134 m³/day as summarized in Figure 9.

The required service water demand for the underground activities is highest during the construction phase when the services area, access tunnels, and initial placement rooms are being excavated; once in operations only additional placement rooms are excavated so water demand lowers. The required average underground service water demand estimates for the construction phase are 102 - 190 m³/day and 33 - 51 m³/day for the operations phase as summarized in Table 10.

The required potable water demand for the underground facilities is up to 4m³/day during both the construction and operations phase.

The total average water demand for both the surface/underground facilities and activities during operations is approximately 134 -189 m³/day (33.5 to 47.3 million litres per year, assuming 250 operating days).

The sourced raw water will be held in the water storage tanks (Area B10). These tanks will be located adjacent to the water treatment plant and pump house building (Areas B11 and B12, respectively). The pump house area will accommodate the potable, fresh and firewater distribution pumps in a single storey engineered structure.

Table 9: Surface Facilities Average Water Demand during Operations

Area	Facility	Process / Consumer	Daily Water Demand
P1	Used Fuel Packing Plant	Module/Basket Decontamination Active Cell Wash Down Cask / Transportation Package Decontamination Building Utilities	22.8 – 39.9 m ³
P5	Auxiliary Building	Laundry and Change Rooms Building Utilities Cafeteria	27.2 – 29.2 m ³
P7	Waste Management Area	Cleaning of Package Exteriors	0.1 m ³
P14	Quality Control Offices and Laboratory	Cleaning and Samples Building Utilities	1.2 – 1.6 m ³
B2	Administration Building	Building Utilities Cafeteria	13 – 22 m ³
B5	Garage	Building Utilities Truck Wash Bay	1.0 – 3.4 m ³
B6	Sealing Materials Compaction Plant	Bentonite Compaction Building Utilities	15.5 – 18.2 m ³
B13	Concrete Batch Plant	Concrete Production Building Utilities Truck Wash Bay	1.3 – 4.3 m ³
N/A	Site-Wide	Dust Control (Spray Truck)	15 m ³
Estimated Total			97 – 134 m³/ day

Table 10: Underground Activities Service Water Average Water Demand

Activity Description	Daily Service Water Demand	
	Construction Phase	Operations Phase
Probe/Pilot Hole Drilling	49.1 m ³	18.2 m ³
Lateral Development	29.3 – 117 m ³	6.0 - 23.9 m ³
Dust Control (Waste Rock Muck Pile)	11.3 m ³	1.3 m ³
Dust Control (Main Access Tunnel)	0 m ³	1.0 m ³
Mobile Equipment Shop Cleaning	1.1 m ³	1.1 m ³
Mobile Equipment Wash Bay	10.4 m ³	5.2 m ³
Concrete Equipment Cleaning	1.1 m ³	0 m ³
Estimated Total	102 – 190 m³/day	33 – 51 m³/day

Measures will be in-place to support a total fire water demand of about 1,360 m³ with 100% redundancy based on the duration of 2 hours at 340 m³/h as stipulated by NBC 2010 and CSA N393-2013. This volume will be stored at the site in a shared fresh/fire water tank. The fire water volume will be kept separate from the raw water by using different draw off points from the tank. Fire water pumps will be packaged as a set containing a diesel, electric and jockey pump.

The water will be distributed through pressure pipes (a dedicated fire main) feeding fire hydrants situated at visible and accessible locations within the vicinity of buildings and other facilities exposed to fire hazards conforming to applicable requirements of CAN/ULC-S520-07, "Standard for Fire Hydrants", as well as those contained in AWWA C502, NFPA 24 and other applicable fire standards and specifications. The Fire Hydrants will generally be located at 60 m spacing to meet the minimum Fire Hydrant spacing requirement as listed in the NBCC.

Potable water will be produced on site at the water treatment plant using the fresh / fire water tank as a supply source. The water treatment plant will be capable of full treatment to provincial safe drinking water standards and a 24-hr supply of treated water will be stored in a potable water storage tank. The treatment plant will be complete with a filtration and sterilization system, filter backwashing equipment with air blowers, backwash pumps and inter-connecting pipework. The final water quality will be monitored for chlorine residual and turbidity.

A dedicated supply system will distribute potable water to all buildings. The system will be capable of providing a peak flow rate of four times the average daily flow rate. Two duty potable water distribution pumps and one standby pump will be installed. A central operations room in the pump house will permit remote control of these pumps.

3.11 SEWAGE TREATMENT PLANT

Area B19

Sewage collected from all serviced buildings will be piped to an on-site sewage treatment plant for treatment to provincial standards prior to recycling or discharge to a local water body. The plant (Area B19 in Figure 4) will be sized to handle 100% of the produced potable water plus a peaking factor of four for the shift changes. Sewage waste from below-ground operations will also be treated in this plant.

A packaged sewage treatment unit such as rotating biological contactor (RBC) or similar system will likely be utilized to handle the liquid waste. The RBC technology employs a fixed growth media process whereby bacteria are grown on a media surface that is rotated into and out of the wastewater. The RBC rotor is enclosed in a steel tank and the system also includes a primary clarifier, final clarifier, ultra-violet disinfection system, controls, switchgear and piping.

Such a modular sewage treatment system can accommodate variations in flow and is fully enclosed, eliminating any tanks and unsightly ponds. Organic loading fluctuations are dealt with easily without affecting the treatment process or effluent quality. Sludge accumulated in the plant would periodically be pumped to a mobile sludge tank and taken off-site for further treatment.

Treated effluent from the plant will be monitored for compliance before being discharged to a natural watercourse or for other uses (e.g., dust control). Laboratory tests will be conducted regularly to ensure that the effluent quality is maintained at the design levels.

3.12 SERVICE WATER AND STORMWATER CONTROL

Areas P10, P17, B15, B26A & B26B

Five ponds will be established on the DGR site, to manage service water, mine dewatering, or stormwater run-off. All the ponds will be lined, as required, over their base and embankments for

protection and to prevent water infiltration back into the ground. Collected flows will, in all cases, be quality monitored and potentially treated before being directed to any downstream uses (e.g., landscape irrigation) or discharged off the site. With regards to the latter, water quality will be analyzed for compliance with the applicable limits as set out in permit for the pond before the pond water is released to a natural watercourse.

The ponds will be designed to settle out suspended particles with any collected mud and silt deposits cleaned out on a periodic basis to maintain design retention volumes at all times. The ponds may be used for the temporary storage of snow and ice removed from the access roads and parking areas during winter months.

Storm Water Management Pond (Area P10)

A perimeter ditch around the Protected Area will direct falling precipitation to this stormwater management pond. The runoff collection ditches, conveyance pipes and culverts as well as the storage pond will be designed for the 1-in-500-year storm event with the pond discharge weir normally closed. The pond dimensions will be about 75 m by 75 m, and it will have a depth of approximately 5 m.

Mine Dewatering Settling Pond (Area P17)

Mine water pumped from the underground dewatering sumps will be piped to a dewatering settling pond. The pond will be designed to have a retention period of 5 days. An allowed freeboard and adjustable weirs on the outlet side of the pond will control the discharge rate and retain floating material such as oil residue collected in the underground sumps.

The mine water in the settling pond may contain sediment (rock dust), nitrogen compounds (arising from the explosives used to excavate rock), salt (due to saline ground water inflow into underground repository), possibly particular metallic elements (notably uranium), and hydrocarbons (oils from equipment). If the concentration of these potential contaminants are above acceptable levels, then the water will be treated before being reused as service water or discharged into a receiving water body.

During construction phase it has been conservatively estimated for design purposes that up to 350 m³/day of water would be pumped to the ground surface. Whereas during the operations phase it is estimated that up to 180 m³/day or less will be pumped to ground surface. These values include both the peak repository-wide underground water inflow and the maximum service water usages as noted in Section 3.10. Conservative maximum values are selected to ensure both the dewatering sump and settling pond designs can handle worst case (peak) operating conditions.

The underground water inflow amounts are generic, conservative crystalline geosphere estimates based on mining operational experience. It is anticipated that groundwater inflows into underground repository at both sites will be lower; particularly, at the South Bruce site with sedimentary rock geosphere. This information will be updated as site investigations advances.

Service Water Settling Pond (Area B15)

Service water high in suspended solids will be directed to this pond which will be designed for a 7-day retention time. Pond dimensions are expected to be about 45 m by 40 m, and it will have a depth of approximately 4 m.

Storm Water Management Ponds (Area B26A & B26B)

Two retention ponds located at opposite ends of the DGR site will receive stormwater run-off collected from the Balance of Site. Similar to the stormwater pond in the Protected Area (Area P10), the ponds will be sized for the 1-in-500-year storm event. The water will be routed to the ponds through a system of conveyance pipes, ditches and culverts, also designed for the aforementioned storm event. The ponds will have a bypass arrangement to directly discharge into the local watercourse if the storm event is continuous, to prevent damage to pond embankments. One pond will measure about 120 m by 50 m and the other pond will be about 90 m by 60 m. Both ponds will have approximately 5 m depth.

3.13 ROADS, PARKING AREAS, BUS SHELTERS AND COVERED PEDESTRIAN ROUTES

Areas B27, P15, B22, & P16

Access Roads

There will be a paved two-lane access road to the DGR site from the existing local highway. In addition, the site facility itself will require a total of approximately 5 km of road network within the Protected Area and the Balance of Site. Private vehicle traffic allowed into the controlled zones will be kept to a minimum with most DGR employees using the main/primary parking lot.

The main access road from the highway will be constructed with a compacted base course and asphaltic surfacing and be provided with shoulders and ditching on both sides. The main access road from the highway will be designed for frequent transfer of heavy loads. The roads and parking pads within the facility will be paved and will be complete with drainage ditches but without any shoulders. Collected on-site runoff from these roads and parking lots will be directed to the stormwater management ponds.

Parking (Areas B27 & P15)

Parking will be available in several locations at the DGR site with the primary parking lot (Area B27) situated adjacent to the Administration Building. This lot will be of sufficient size to accommodate cars, buses and trucks requiring parking services at the DGR facility. Unobstructed parking will further be ensured for all fire and security vehicles. An additional parking area (Area P15) will be provided in the Protected Area near the Auxiliary Building and the quality control offices and laboratory for deliveries as well as fire and security vehicles.

Bus Shelters (Areas B22)

Bus shelters (Areas B22-A & B22-B) will be located in the main parking area adjacent to the Administration Building as well as in the vicinity of the water treatment plant and air compressor building (Areas B11 and B8, respectively). All shelters will be complete with sliding doors, benches and heat to keep the occupants warm during winter.

The bus shelters in the main parking area are expected to be used by staff commuting to the DGR site.

Covered Corridor / Pedestrian Routes (Area P16)

Covered corridors or pedestrian routes will be established to facilitate personnel movement between the Administration Building, Auxiliary Building, UFPP and the Service Shaft Complex. The covered corridors will allow easy access and movement between buildings during winter and other harsh weather conditions.

Corridors will be located so as to allow vehicle traffic to circulate the facility in an efficient manner. Adequate space will be provided for pedestrians to share the passageways with handcarts. The corridors will be climate controlled (insulated and heated). Windows and doors will be installed as required for safety, and fire protection measures will be in place along the corridor lengths.

3.14 OTHER SURFACE FACILITIES

Areas B8, B9, B18, B21 & B23

Air Compressor Building (Area B8)

Air compressors will be required for supplying service air to the surface facilities and underground repository, and emergency breathing air to the UFPP, and underground refuge stations. Compressed will be delivered using 3 rotary screw compressors (with one standby). Service air will be delivered at a rate up to 0.12 m³/s. Breathing air, required for underground in the refuge stations and on surface in the UFPP, will be delivered at a rate of 0.23 m³/s by the same compressors that supply service air.

Fuel Storage Tanks (Area B9)

A fuel storage area will store diesel and gasoline fuel in accordance with applicable requirements listed in the NFPA 30, Flammable and Combustible Liquid Code. The tanks will be located within a concrete-lined containment area with sufficient capacity to hold the volume of the largest tank plus 10%.

Tanker fuel pumps or dedicated loading pumps will be used to fill the storage tanks and fuel will be dispensed through a metered fuel dispensing station. Card readers will be in place at the dispensing station.

Storage Yard (Area B18)

The storage yard will be an open area reserved for the laydown and temporary storage of new and decommissioned equipment and materials. It will have a granular surface and be fenced with lockable access gates.

Helicopter Pad (Area B21)

An area adjacent to the main parking lot will be dedicated for a helicopter landing pad. The helipad's clear area will be 30 m in diameter and will be capable of receiving a single helicopter while also allowing for parking on the pad. The landing pad will be designed with proper navigational aids and lighting requirements.

Weigh Scale (Area B23)

A weigh scale will be provided to properly monitor the receipt of bulk materials to the DGR facility as well as the shipping of excavated rock off-site. The scale will be sized to accommodate a fully loaded tractor and a double trailer for an overall length of 25 m. The scale will be supported by fully automatic controls, signal lights for traffic management and a motion detection system.

3.15 EXTERNAL FACILITIES AND OPERATIONS

This section describes facilities that will be located outside the security boundaries of the DGR facility and established to support the DGR facility development and operations. Such facilities will include an area for management of excavated rock, accommodation for construction personnel and a Centre of Expertise. A pumphouse will also be situated off-site for supply raw water to the DGR facility.

3.15.1 Excavated Rock Management Area Area B1

It is expected that most of the excavated rock will not be suitable or required for concreting, road works or backfill at the DGR facility. Excavated rock will not be used for production of LHHP concrete and various sealing material. It is also conservatively assumed that the excavated rock will not be released for commercial use (e.g., as a source of aggregate for road works or concrete). Therefore, a facility will be required for the long-term management of about 2.5 million cubic metres (broken volume) of excavated rock.

The Excavated Rock Management Area (ERMA) will be located outside the perimeter fence of the DGR surface facilities; the location will be selected to avoid streams and wetlands. It is assumed that the ERMA will be located within a 5 km distance of the DGR surface facilities and will occupy an area of approximately 25 Ha (~500m x 500m) depending on height of rock pile. The maximum height of the rock pile is expected to be between 15 to 20 m. The ERMA will be fenced.

The topography of the Ignace area location (crystalline) is undulating and forested. The ERMA will initially be prepared by clearing and grubbing any vegetation and then stripping and stockpiling topsoil. The low-lying depressions will then be filled with excavated rock to create a level working surface. Excavated rock will be delivered by haul truck from the Service Shaft Complex then be placed and compacted in layers on the prepared surface. Access routes and paths will be prepared on the rock pile for movement of trucks and grading equipment.

The topography at the South Bruce area location (sedimentary) is relatively flat in a farmland setting. The ERMA will be prepared by clearing and grubbing any vegetation and then stripping and stockpiling topsoil. Fill material will be placed and compacted to create a level working surface for the excavated rock. The excavated rock will be delivered by haul truck, and then placed and compacted in layers on the prepared surface.

The ERMA will have a perimeter ditch for collecting run-off from the rock pile and will direct run-off water to a stormwater management pond. The ditches will be hydroseeded and riprap lined

to prevent erosion. An external ditch system may be employed to prevent run-off from surrounding areas from entering the perimeter ditch around the ERMA.

A storm water management pond (Area B20) will be used to collect and monitor the run-off from the rock pile before being released to the environment. The pond will be used to control water discharge within design criteria for water quantity, water quality and total suspended solids. The pond will be designed to hold water for a sufficient amount of time to allow settling of suspended solids. The pond will create a single location to measure the quality of run-off from the rock pile. The potential contaminants of concern in the run-off will likely be various chemical constituents due to the dissolving of minerals in the excavated rock into the water and release of nitrogen compounds from residual explosives on the excavated rock.

Should future site investigations find the rock at site to be acid generating, then the ERMA will be designed to limit the amount of potentially contaminated water (leachate) that could seep into underlying soil and rock. This will be achieved by first creating a level working surface at the ERMA and then covering this surface with a composite or multiple-layer liner system. Excavated rock will be placed on this liner. The liner will be sloped towards the perimeter ditch water system that surrounds the ERMA. The perimeter ditch will also have a liner to ensure all potentially contaminated water is directed to a lined stormwater management pond where water would be treated as necessary before release.

The rock pile will be rehabilitated after excavated rock placement has ended. The pile will be restored by vegetating the surface with native plant species and in manner capable of supporting a self-sustaining ecosystem.

3.15.2 Accommodation for Construction Personnel

During the initial construction period, accommodation will be required for the construction personnel. These workers could be housed in the community and surrounding area, or there could be a need to develop a nearby temporary infrastructure to provide sleeping quarters, kitchen, dining, laundry, medical and recreational facilities.

NWMO will work with the community and surrounding areas to plan for and contribute to the development of community infrastructure required during construction and operation to house and integrate personnel into the community. It is assumed that accommodation is required for about 600 construction personnel.

If required, a temporary facility to provide construction accommodation will be developed in collaboration with the community. Typically, they will be two storey buildings with units whose internal layout will vary depending on the intended occupancy. Some units will feature rooms with larger sleeping quarters and private bathrooms to be intended for management and supervisory personnel. Other units will comprise of rooms with one or two beds and shared toilet facilities. Common areas will also be provided.

In addition to the residential structures, other required support facilities and systems will include the following:

- Security fencing including access gates around the facility as well as area and security lighting;
- Access roads and parking;
- Power generation and distribution systems (electrical power will initially be supplied by generators) and fuel supply;
- Water, stormwater, sanitary sewage and solid waste facilities as well as a telecommunications system;
- Fire detection and protection systems;
- Kitchen, dining, laundry and recreation facilities; and
- Medical centre (e.g., nursing station).

3.15.3 Community Infrastructure

The NWMO is transitioning to a site-specific project. The incremental addition to community infrastructure will be determined through discussions with the communities based on a mutual understanding of the existing capacity of the infrastructure and the anticipated demand that is expected to arise with the implementation of the project.

3.15.4 Centre of Expertise

A Centre of Expertise will be established in the community selected to support ongoing detailed site evaluation. The centre will be located in or near the community, as determined with people who live in the area. Its purpose will be to support the multi-year testing and assessment of the site on technical safety and community well-being related dimensions, which are key components of the site selection process. The Centre of Expertise will be home for an active technical and social research program and a technology demonstration program during this period, involving scientists and other experts in a wide variety of disciplines, including geoscience, engineering, environmental, socioeconomic and cultural impact assessment fields.

An engineering test facility will be located at the Centre of Expertise. Potential activities in the engineering test facility may include testing of prototype systems for the Used Fuel Packaging Plant (UFPP) (e.g., mock fuel handling, container welding, copper coating, etc.), as well as the development of container placement equipment for the underground repository. The engineering test facility may also house demonstration equipment to show key repository packaging and container placement processes.

The Centre of Expertise may be expanded to support construction and operation of the deep geological repository. The centre will become a hub for knowledge sharing across Canada and internationally. Artist renderings of what the Centre of Expertise could look like are shown in Figure 27.

Design details of the Centre of Expertise will be developed with the interested community, potentially affected First Nation and Métis communities and surrounding municipalities with their preferences in mind.



Figure 27: Centre of Expertise concepts

4. SHAFTS, HEADFRAMES, AND HOISTING SYSTEMS

This section describes the three Shaft Complexes (Main, Service, and Exhaust Ventilation Shafts) required to support the construction, operation, and extended monitoring of the DGR. The Main Shaft, Service Shaft and Exhaust Ventilation Shaft which are identified as Areas P2, P4 and P20, respectively, shown in Figure 4.

4.1 HEADFRAMES AND HOISTING SYSTEMS DESIGN

The shafts will be serviced by a total of five hoists that are housed in three headframes. The Main Shaft cage, Service Shaft cage and development skips, which will be raised/lowered by friction hoists. The remaining two hoists will be Blair-type hoists that will be used to raise/lower auxiliary cages for movement of personnel. The following sections describe the headframe structures and various hoisting systems to be used at the DGR facility.

4.1.1 Main Shaft Headframe and Hoist

The Main Shaft Complex will serve as the exclusive conveyance structure for the surface-to-underground transfer of the Buffer Boxes (with UFCs) for placement in the underground repository. Additionally, if there is a need in future, the Main Shaft will also accommodate the transfer of any retrieved UFCs from the repository level to the surface.

The Buffer Box weight and dimensions are described in Appendix A. The intended mode of buffer box transfer to the underground repository is via trolley. Each Buffer Box with a UFC will be loaded into a transfer cask and then placed onto a trolley.

The Main Shaft hoisting system will be tower-mounted within an approximately 60 m high slip-formed reinforced concrete headframe structure. The use of a concrete headframe will provide a sturdy and resilient structure, and a system that will afford a high level of protection against any potential meteorological or seismic-related impacts. The facility will be insulated wherever possible to maximize its energy efficiency. Immediately adjacent and joined to the head frame structure will be a collar house, which will house the facility for loading the transfer cask onto the cage. The head frame will have various floors, including one floor for the Koepe hoist, a deflection sheave floor, the collar floor, and a sub-collar floor, in descending order.

The Main Shaft will use a friction hoist which will have a payload capacity of approximately 60 tonnes. Such a hoisting system will have a nominal 100-year life, assuming the adoption of appropriate preventative maintenance practices and component upgrade schedules. The Main Shaft's friction hoist system, comprising one main cage with a counterweight in balance, will be configured as noted in Table 11.

Table 11: Main Shaft Hoisting Systems

Item	UFC Hoist
Configuration	Koepe Friction Hoist
Weights / Payloads	
➤ Approximate Tare with Attachments	50 tonnes
➤ Approximate Payload	60 tonnes
➤ Approximate Counterweight with Attachments	80 tonnes
Suspended Load	280 tonnes
Hoist Speed	2.5 m/s
Required Motor	1,000 kW

Note: Required payload capacity of Main Shaft may change as design of UFC, Buffer Box, transfer cask and trolley evolve.

4.1.2 Service Shaft Headframe and Hoisting Systems

The Service Shaft Complex will be a multi-purpose hoisting facility with three hoisting systems for movement of personnel and materials into and out of the repository. The hoisting systems will be tower-mounted inside an approximate 50 m high slip-formed reinforced concrete headframe structure. The headframe structure will be designed to maximize durability and weather-tightness to ensure a long service life. The head frame will have 7 floors, consisting of 3 hoist floors, one power floor, one dump floor, the collar floor and a sub-collar floor, in descending order. The Service Shaft Complex will also have a collar house and a bin house for handling excavated rock brought to surface. The headframe will be equipped with a rock dump and chute to direct the excavated rock into a temporary storage bin or onto the ground. From this location the excavated rock will be loaded onto haul trucks which will take the rock to the ERMA.

The following hoisting systems will raise/lower the equipment and cages inside a 7-m-inside diameter concrete lined shaft:

- Excavated rock friction hoist for raising/lowering two counterbalanced skips;
- Main service friction hoist for raising/lowering a cage for personnel movement and material handling; and
- Auxiliary Blair-type hoist for raising/lowering cage for personnel movement both during normal operations and emergencies.

A key reason for selecting the Blair-type hoist for raising/lowering the auxiliary cage in this shaft as well as the Exhaust Ventilation Shaft is that this hoisting system avoids the use of combustible materials in the shaft. Single-rope drum hoisting systems must use wooden guides to allow use of “safety dogs” for catching the cage in the event of rope failure. Whereas Blair-type hoisting system uses two ropes and in the event of a rope failure the second rope will safely support the

cage. Thus, in a Blair-type hoisting system steel guides can be used to control movement of the cage within the shaft.

The details of the Service Shaft hoist systems are presented in Table 12.

Excavated Rock Hoist

The Service Shaft Complex will incorporate the permanent excavated rock handling installation for the DGR. A friction hoist will raise and lower skips (large metal buckets for handling rock) with excavated rock that is generated by the development of the underground repository both during initial construction and operation phases. The two bottom-dump skips will be in a balanced arrangement on the friction hoist.

The skips will be loaded at the loading pocket near the base of the Service Shaft. Excavated rock or muck will first be delivered by haul trucks to a grizzly (heavy duty screen with approximately 250 mm openings) above a raise that feeds the loading pocket. The oversize material will be broken with the use of a hydraulic rock-breaker until it fits through the grizzly.

The loading pocket (as shown in Figure 28) will consist of conveyor and two bins or flasks that are weight controlled. Feed to the bin/flasks from the raise will be via a conveyor, to allow for fine control on the load levels in each skip. Each flask will be filled with a measured amount of excavated rock during the skip cycle. Upon the skip's arrival in the loading pocket the weighed rock will be transferred into the skip via a chute from the corresponding bin/flask. The loaded skip will be raised to surface where the rock will be dumped into the bin house.

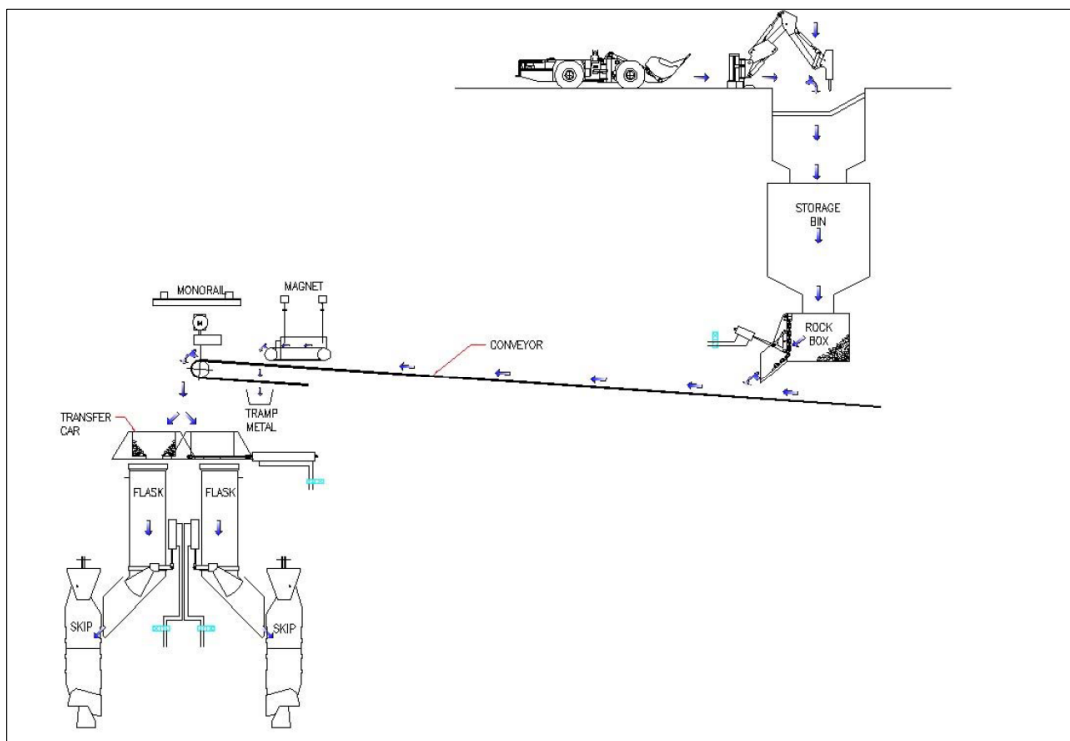


Figure 28: Typical Loading Pocket Arrangement

Service Hoist

The Service Shaft will be equipped with a friction hoist and cage (with a counterweight in balance). The service hoist will move personnel, consumables and equipment into and out of the underground repository. It will also be used to move sealing material components such as HCB blocks and bentonite gap fill materials (GFM) from the surface to the repository. It will be able to carry up to 50 personnel or handle loads up to 10 tonnes.

The Service Shaft, as an excavated rock handling shaft, will require additional maintenance relative to the other two shafts. Because there is a possibility that loose rock will fall down the shaft and into other shaft compartments, the muck handling compartments will be separated from other compartments over the full height of the shaft by brattice panels. Brattice panels are frames with cladding on the inside which act as a physical barrier between compartments and will prevent loose rocks from falling into the other hoisting compartments.

Auxiliary Hoist

The Service Shaft will be equipped with a Blair-type auxiliary hoist and cage. The auxiliary hoist will be available in the Service Shaft to move personnel into and out of the underground repository on an as needed basis without interrupting the movement of materials. This hoist will provide a second means of egress for personnel during an emergency event. In the event that main electrical power supply is lost, electrical power will be supplied to the auxiliary hoist by emergency power generators.

Table 12: Service Shaft Hoist Systems

Item	Hoist for Excavated Rock (Development Skips)	Service Hoist/Cage	Auxiliary Hoist/Cage
Configuration	Koepe Friction Hoist	Koepe Friction Hoist	Blair Multi-rope Hoist
Weights/Payloads			
➤ Tare with Attachments	10 tonnes	10 tonnes	2.3 tonnes
➤ Payload	6.5 tonnes	10 tonnes	1.8 tonnes
➤ Counterweight with Attachments		15 tonnes	
Suspended Load	40 tonnes	50 tonnes	7 tonnes
Hoist Speed	5 m/s	2.5 m/s	2.5 m/s
Required Motor	300 kW	300 kW	75 kW

4.1.3 Exhaust Ventilation Shaft Headframe and Hoisting System

The Ventilation Shaft Complex will handle most of the repository exhaust air and will have an auxiliary hoist to provide a secondary means of egress for personnel during an underground emergency event. The 30 m high steel headframe structure will have a single operating floor to support the deflection sheave, plus the collar floor and sub-collar. The collar house will be able to support mine rescue or evacuation efforts.

The Blair-type hoisting system will be ground-mounted beside the steel headframe structure. Like the Service Shaft auxiliary hoist, in an event that main electrical power supply is lost, electrical power will be supplied to the auxiliary hoist by emergency power generators. The details of the Exhaust Ventilation Shaft's hoist system are as shown in Table 13.

Table 13: Exhaust Ventilation Shaft Hoist System

Item	Auxiliary Hoist
Configuration	Blair Multi-rope Hoist
Weights/Payloads	
➤ Tare with Attachments	2.3 tonnes
➤ Payload	1.8 tonnes
Suspended Load	7 tonnes
Hoist Speed	2.5 m/s
Required Motor	100 kW

4.2 SHAFT DESIGNS

The primary design elements of the three shafts are dictated by hoisting requirements for personnel, materials and equipment, as well as emergency egress considerations and underground services needs. The Exhaust Ventilation Shaft diameter is set by ventilation requirements and, in particular, a requirement to maintain the up-cast air velocity in the shaft outside the range of 7 to 13 m/s to avoid suspension of water droplets.

Taking in account these various design considerations, the inside diameter of the three shafts have been set at 7 m. An advantage of standardizing inside diameters is standardization of shaft sinking operations which will lead to a more efficient shaft sinking program. The shaft liner designs will be finalized once a final DGR location has been selected and geologic conditions have been defined at each shaft location and the design parameters finalized. Future design considerations will include possible removal of reinforcing steel to facilitate liner at the time of decommissioning and, if required and depending on site conditions, design features to control water inflow through the liners into shafts.

The following sections describe the conceptual layouts for each of the shaft. These sections make reference to Figure 31 for the Main Shaft, Figure 32 and Figure 33 for the Service Shaft, and Figure 34 for the Exhaust Ventilation Shaft, respectively.

4.2.1 Main Shaft

During the Operations Phase, the Main Shaft Complex will serve as the exclusive conveyance structure for the surface-to-underground transfer of the UFC/BB Transfer Cask for placement in the underground repository. Additionally, based on future needs, the Main Shaft will also accommodate the transfer of any retrieved UFCs from the repository level to the surface.

A secondary function of the Main Shaft will be to act as a conduit for exhaust ventilation air from the underground temporary UFC/BB Transfer Cask storage/staging area located near the base of the Main Shaft. At the surface, the air will exhaust to the atmosphere via a plenum which leads to a 9-m-high ventilation stack that will be located close to the Main Shaft headframe. A plenum is an underground structure that directs air out of the shaft envelope to a location away from the headframe.

The Main Shaft will also provide access to an underground repository for some services. The shaft will have separate compartments for:

- Cage for transfer of the UFC/BB Transfer Casks;
- Counterweight; and
- Shaft-specific Communications Cable(s).

The Main Shaft (Figure 31) will have a finished internal diameter of 7 m with a 500 mm thick reinforced concrete liner. The Main Shaft hoisting system will be tower-mounted within an approximately 60 m high reinforced concrete headframe structure. The use of a concrete headframe will provide a sturdy and resilient structure and a system that will afford a high level of protection against any potential meteorological or seismic-related impacts. The facility will be insulated wherever possible to maximize its energy efficiency. Immediately adjacent and joined to the head frame structure will be a collar house, which will house the facility for loading the UFC/BB Transfer Cask onto the cage. The headframe will have multiple floors, including one floor for the Koepe hoist, a deflection sheave floor, the collar floor, and a sub-collar floor, in descending order. The hoisting system will be designed to operate with a hoisting speed of 2.5 m/s, alignment integrity and guide wear will not be an issue with respect to ongoing maintenance needs.

During the Construction Phase, the Main Shaft will be used to mobilize large heavy equipment underground, support general material handling logistics, and to support the underground demonstration facility (UDF) activities, for example, the movement of non-nuclear UFC/BB Transfer Casks for placement in the UDF area. The commissioning of the Main Shaft will be linked to the transition of the Exhaust Ventilation Shaft to full Operations mode ventilation versus supporting the initial underground development works.

4.2.2 Service Shaft

The Service Shaft (Figure 32 and Figure 33) will have a final finished internal diameter of 7 m with 500 mm-thick reinforced concrete liner. The primary functions of the Service Shaft will be delivery of personnel and materials to and out of the underground repository, to act as a conduit for delivery of fresh to underground repository, and to provide primary access to underground repository for services.

The Service Shaft will have separate compartments for:

- Equipment to deliver excavated rock to ground surface (skips);
- Cage to move personnel and materials to the underground repository and compartment for an associated counterweight;
- Auxiliary cage for personnel movement during normal operations and emergencies; and
- Services including service and potable water pipes, two high voltage power cables, communications cable, compressed air pipe and two concrete slicklines.

All conveyances will run on steel guides. There will be a ventilation plenum to connect the fresh air intake to the shaft. The plenum will allow the fresh air intake fans to be located away from headframe and thus reducing noise levels in the vicinity of the headframe.

At the bottom of the Service Shaft, the loading pocket will have some spillage during its operation. A ramp will be developed to the shaft bottom so that equipment can travel to the shaft bottom on a regular basis to remove broken rock.

4.2.3 Exhaust Ventilation Shaft

The Exhaust Ventilation Shaft (Figure 34) will have a finished internal diameter of 7 m with a 500 mm thick reinforced concrete liner. The primary functions of the Exhaust Ventilation Shaft will be to act as a conduit for exhaust ventilation air from the underground repository, to provide a secondary means of egress during an underground emergency event, and to provide access to underground repository.

The Exhaust Ventilation Shaft will have separate compartments for:

- Exhausting air from the underground repository;
- Auxiliary cage for personnel movement during emergencies; and
- Services including service and potable water pipes, dewatering pipe, two high voltage power cables, communications cable, and compressed air pipe.

The shaft diameter has been set at 7 m to ensure the ventilation air velocities will remain below or close to 7 m/s.

The main exhaust fans will be located underground at the DGR level and will push air up the exhaust ventilation shaft. At surface the air will exhaust via a plenum which leads to a 15-m-high ventilation stack that will be located close to Exhaust Ventilation Shaft headframe (see Figure 29).

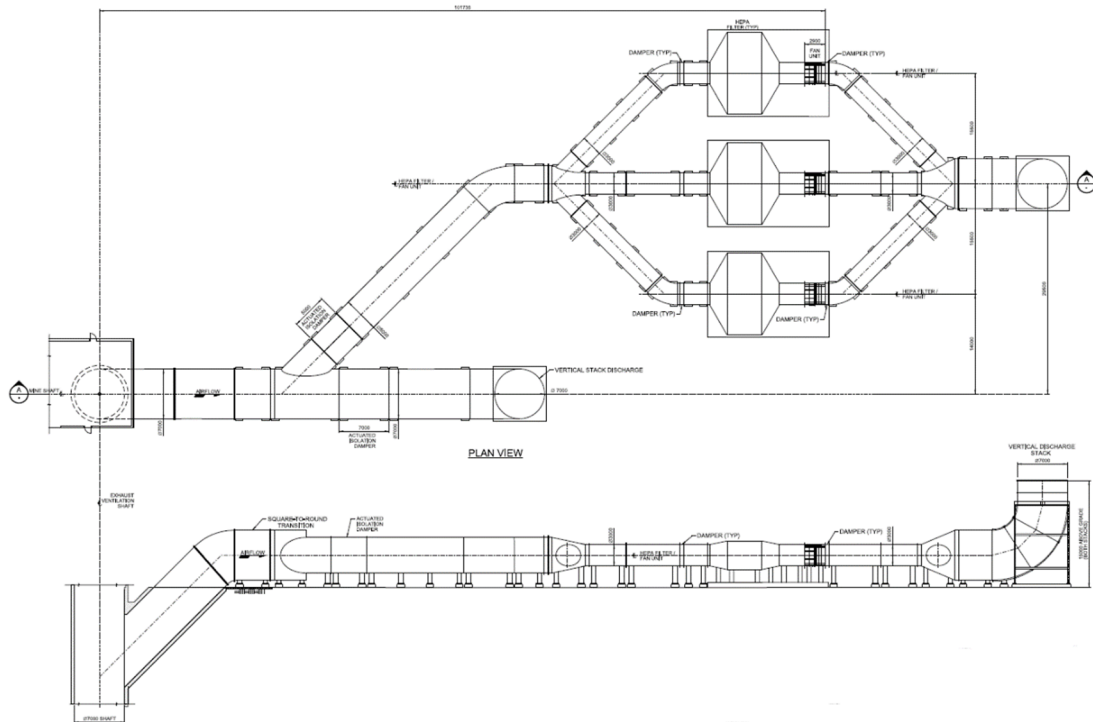


Figure 29: Conceptual Exhaust Ventilation Shaft Exhaust Stack & HEPA Filters Arrangement

4.3 SHAFT SINKING REQUIREMENTS

NWMO's current planning assumption is that the three shafts will be developed using a conventional controlled drill and blast sinking approach. It is envisaged that the Main Shaft and Service Shaft will be sunk using the permanent concrete headframes. Whereas the Exhaust Ventilation Shaft will be sunk utilizing temporary head frame in lieu of using the final headframe. As the site investigation and the construction plan advances, other shaft excavation techniques (e.g., Raise Bore Excavation) will be investigated.

The design of the shaft liner and grouting system (if grouting is required), will be completed after the location of the shaft (and site) is established. The shaft liner will serve two purposes; first it is a measure of ground support, preventing minor ground shifts or loose rock from falling into the shaft, and second it will act as a means to prevent seepage of water in the shaft. It is expected that the host geosphere for the underground repository will consist of a very good quality rock mass, one that is only moderately to sparsely fractured and with a low permeability. However, it is possible that the near surface rock will have permeable features where water could flow into the shaft excavation. These zones of higher inflow rates will be addressed through grouting and the liner design.

The shaft sinking process itself involves several steps, which will include:

- Collaring or starting the shaft;
- Setting up the equipment needed to sink the shaft;
- Sinking the shaft to its full depth including significant allowances for geoscience verification activities of each round and any notable geologic features;
- Dismantling the equipment used for sinking; and
- Installing the permanent equipment and its commissioning.

The Service Shaft and Exhaust Ventilation Shaft will be sunk concurrently. The sinking crew from the first shaft to be completed will then move the Main Shaft.

4.3.1 Shaft Collaring

Collaring the shaft requires the establishment of the shaft centerline via survey, and usually requires the drilling of a borehole to confirm rock type and quality. The borehole will be drilled within the finished diameter of the planned shaft to at least the planned depth of shaft bottom.

Once the location is confirmed, the shaft excavation will commence. This will involve use of controlled dill & blast techniques to establish the rough diameter of the shaft to an approximate 30 m depth. Removal of excavated rock or muck will be accomplished using a crane equipped with a bucket, and a small excavator, which will be lowered into the excavation to load the bucket. Once the desired depth is achieved, a set of forms will be installed close to the bottom, and the permanent concrete liner for the collar will be poured into place.

If the shaft is first excavated through overburden, then a similar process will take place, with the excavation through ground being carried out with a small excavator that is captive in the hole until the bedrock is reached. During excavations, temporary support of the walls will be provided using liner plates and ring beams, which will be bolted into place. Once bedrock is reached, a drill will be lowered into the hole and a 5 m cut will be sunk into the excavation's bottom to act as a water-proof socket for the shaft liner, preventing influx at the rock / overburden interface. With the cut completed, a set of shaft forms will be lowered into the hole, and the concrete collar will be poured from the bottom up.

At the sedimentary rock location, it is likely that the top 180 to 200 m of bedrock will require ground conditioning to limit the amount of groundwater inflow during shaft sinking. Ground conditioning would be achieved by either grouting or ground freezing. The upper 180 to 200 m of the concrete liner will be designed to limit ground water into the finished shaft.

4.3.2 Sinking Plant Set-up

Once the collar is established, the equipping of the sinking plant will commence. The sinking plant has four main elements as listed below:

- Sinking hoist;
- Sinking winches;
- Sinking headframe; and
- Galloway (or sinking stage, see Figure 30).

The sinking hoist will be a double drum hoist, equipped with two sinking buckets to both move personnel and material into the shaft excavation, and to remove excavated rock from it as it is excavated. The sinking winches (2 to 4 required) are smaller low speed hoists that will be used to raise and lower the Galloway as required during the sinking cycle.

The sinking headframes for the Main Shaft and Service Shaft will be the permanent slip-formed concrete headframe structures. The concrete headframes will be constructed in advance of shaft sinking and will be used to raise/lower shaft sinking equipment. Once shaft sinking has been completed, the temporary hoisting equipment that is housed in these headframes will be removed and the permanent hoist systems will be installed.

The sinking headframe for the Exhaust Ventilation Shaft will be a temporary steel structure that supports the ground-mount sinking hoists and winches. The temporary headframe will be approximately 40 m high to accommodate travel room for the hoisting plants, and to allow for the lowering of items like drill jumbos and mobile equipment into the shaft. A temporary enclosure attached to the headframe, called a collar house, will be in place to shelter workers from the elements and to temporarily house material and equipment.

Once the Exhaust Ventilation Shaft is sunk a temporary rock loading system will be installed at the DGR level. This system will be used to remove rock that is generated by the development of the underground repository during initial construction. This system will be used until the permanent skipping facilities are installed in the Service Shaft.

A shaft sinking stage or Galloway is a multi-decked structure that is supported by the sinking winches in the shaft (Figure 30). The stage is not attached to or supported by the shaft walls, and it hangs independently. It is an integrated development and excavation system, wherein all aspects of the shaft development effort are completed from the one structure including drilling, mucking, ground control and liner installation. It contains all working needs, including small tools, shaft sinking drills or jumbos, and shaft liner forms.

Each deck within the Galloway has a different function, and each Galloway is unique to the shaft under construction. Because the shafts in this case are the same diameter, it will be possible to use similar Galloway designs in each shaft.

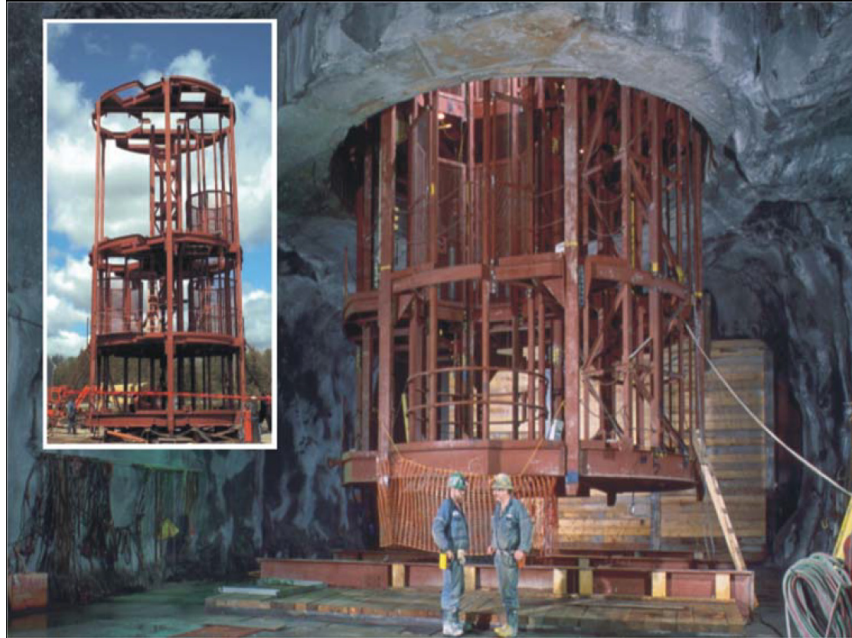


Figure 30: Typical Galloway Showing the Pre-Assembly on Surface

4.3.3 Shaft Sinking Operations

The basic process of sinking a shaft will be methodical and repetitive, as follows:

- The face (or exposed bottom) of the excavation will be cleaned and prepared for drilling;
- The shaft jumbo will be lowered to the face and the round is drilled;
- The jumbo is lifted clear, and the holes will be loaded with explosives;
- The workers will be brought to surface, the Galloway will be lifted clear to a safe distance and the round will be blasted;
- The shaft will be ventilated to clear blast gases prior to workers being allowed to re-enter;
- Workers will begin excavating the bottom of the shaft and installing ground control (i.e., rock bolts, screen) in the shaft walls. Geological inspections will be undertaken across the shaft walls and face during this time;
- The shaft liner will be formed and poured, extending it down closer to the face; and
- Once the face is cleared of excavated rock, the cycle will be repeated.

An average rate of advance for the shaft sinking will be between 2.5 m and 3.5 m per day. However, for planning purposes it is assumed that geoscience verification activities will occur for each round which will reduce the advance rate.

4.3.4 Dismantling the Sinking Gear

Once the shaft bottom is reached, the entire sinking system will be dismantled to allow for production equipping. This will require dismantling of the shaft sinking stage or Galloway and its hauling to the surface. The shaft sinking buckets will then be removed, the various ropes used will be re-wound and taken off the headframe. At the Exhaust Ventilation Shaft the temporary headframe will be removed and the permanent headframe will be constructed in its place.

4.4 SHAFT OPERATIONS AND MAINTENANCE

The three shafts have been designed to promote uniformity wherever possible, so that repeat maintenance events will be as similar as practical in terms of the sequence of events, equipment required, and manpower needs.

During normal operations, Ontario regulations stipulate a minimum number of shaft inspections per week. During the weekly inspections all shaft compartments will be examined with damage noted and with loose materials cleaned out. Maintenance will be scheduled as required.

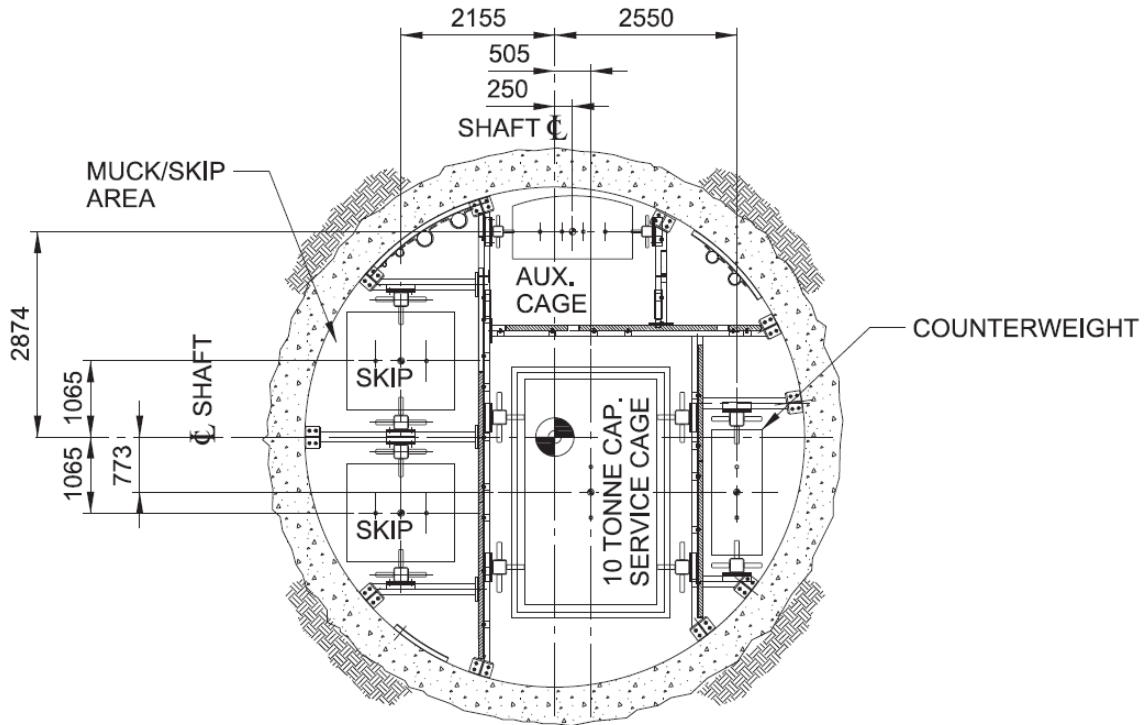
There will be regular testing of the hoisting and braking systems. The hoisting systems, including ropes, conveyances and hoisting equipment will also be inspected on a periodic basis to ensure that they are in proper condition and fit for continued use.

Hoist ropes will be periodically changed and will also be subject to regulatory requirements to have sections cut from the ends for destructive testing. This will require that conveyances be temporarily chaired (locked into position) or supported at the collars while head ropes are disconnected for inspection or change-out. Likewise, for the friction hoists, new tail ropes will need to be installed using small tuggers or winches to pull the ropes up the shaft during these operations.

A general maintenance/replacement schedule is presented in Table 14. The Service Shaft, as an excavated-rock-handling facility, will require additional maintenance as compared to the other two installations.

Table 14: Shaft / Hoist General Maintenance and Replacement Schedule

Item	Replacement Frequency	Notes
Hoist Ropes	3 to 9 years	Depends on the findings of regulatory rope inspections. It should be assumed that all hoist ropes will be replaced every 3 years except for Exhaust Ventilation Shaft auxiliary hoist ropes. Due to low usage ropes in Exhaust Ventilation Shaft would be changed up to every 9 years.
Hoist Conveyances	5 years for skips 10 years for cages	Depends on inspections. If conveyance is not displaying fatigue or wear, it may be used longer.
Hoist Brake Liners	5 years	
Hoist Bearings	25 years	Depends on hoist alignment and balancing. Well balanced and lubricated machines will last longer.
Hoist Motors	25 years	Rule of thumb
Hoist Drives	25 years	Due to obsolescence and availability of spares, may need to replace components every 10 years.
Hoist Replacement	50 to 100 years	The oldest hoists in operation are 95 years old and there few hoists that have reached this age. Current assumption is to perform a full hoist replacement in 50 years.



7.0m ϕ SERVICE SHAFT PLAN

Figure 32: Service Shaft – Shaft Plan

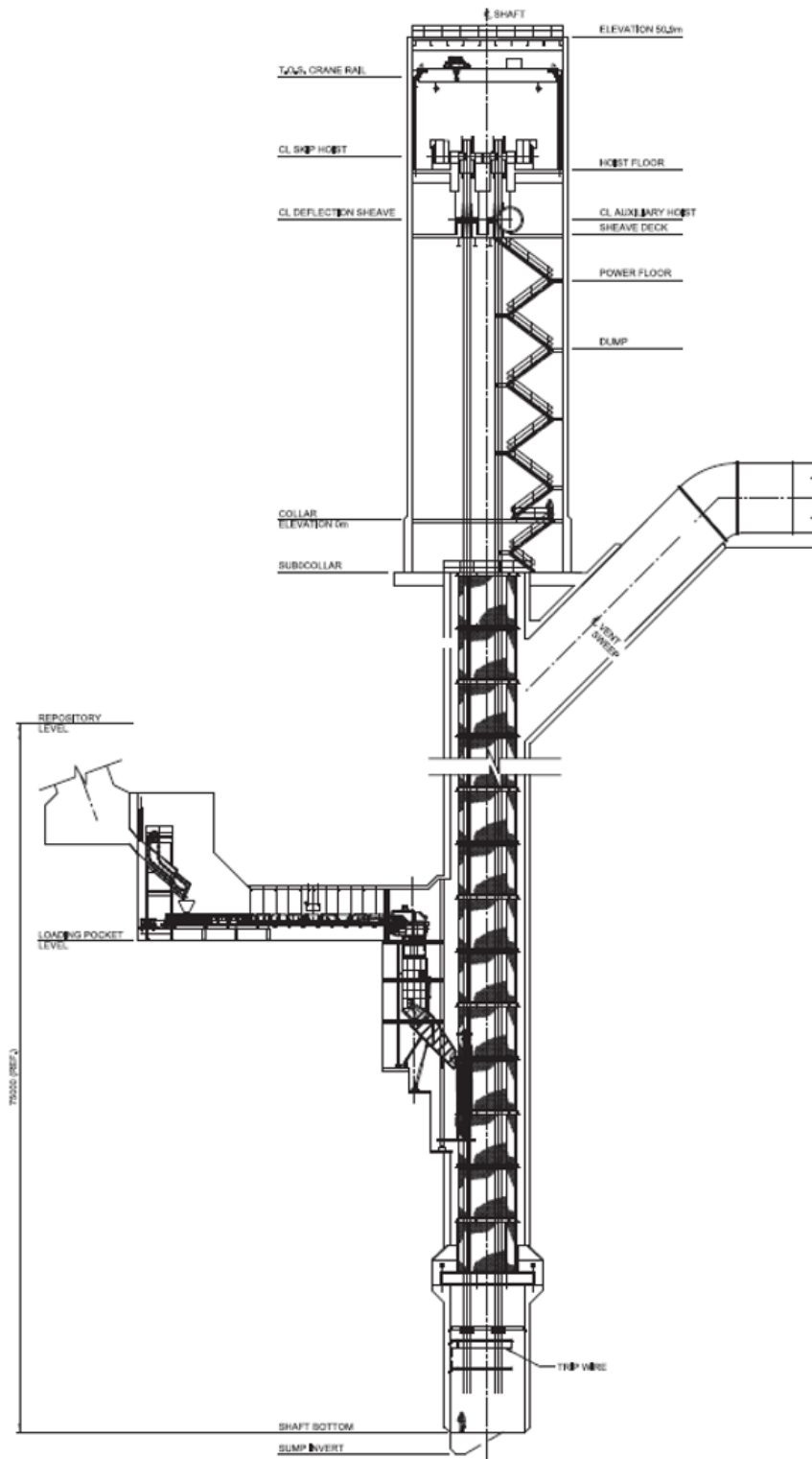
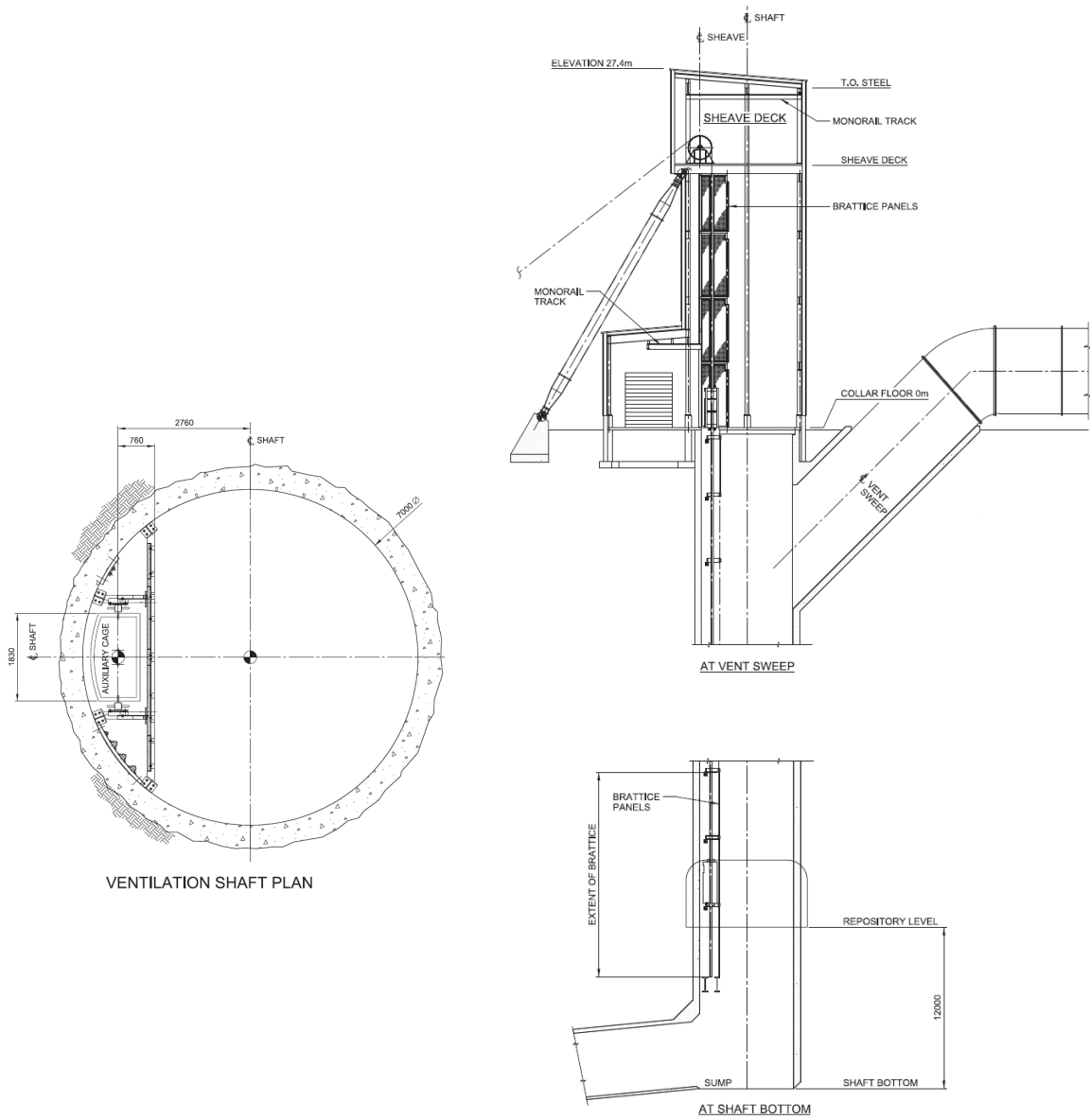


Figure 33: Service Shaft - Shaft and Headframe Section



Shaft Plan

Shaft and Headframe Section

Figure 34: Exhaust Ventilation Shaft

5. UNDERGROUND FACILITIES

There will be two main components to the underground operations of the DGR: the Services Area and the main repository with placement rooms that will contain the buffer boxes (with UFCs). The Services Area will provide a range of facilities to support the DGR's operations including:

- Underground Demonstration Facility (UDF);
- Refuge station, offices, washrooms;
- Maintenance shop and warehouse;
- Battery charging station;
- Underground equipment / material storage areas;
- Explosives and detonators magazines;
- Main electrical substation; and
- Truck dump equipped with grizzly and rockbreaker.

Twin access tunnels will branch out from the Services Area into the placement area. Within the placement area the placement rooms will be divided into panels that will be located along the repository arms. The placement room length will range approximately between 305 m to 342 m for both the crystalline and sedimentary underground repository concepts.

During the construction period, the Services Area, including the UDF, twin access tunnels that extend into each repository arm and one panel of rooms would be developed. Following the start of operations, excavation of placement rooms would proceed concurrently with placement activities. Sequencing of the development (excavation) and UFC placement activities will provide for adequate separation of these two major activities from a manpower, ventilation and equipment perspective.

The placement rooms will be developed at a single horizon along with the various facilities, and infrastructure. The basic arrangement of the underground repository will involve a series of parallel, dead-end placement rooms, organized into panels. All underground openings will be excavated by drill and blast methods. The placement rooms will have a rectangular shape of nominal dimensions 3.2 m wide by 2.4 m high. There will be room-to-room spacing of 25 m, and an in-room container-to-container spacing of approximately 1.3 m and 1.7 m for the crystalline and sedimentary rock layouts, respectively.

The in-room placement of the Buffer Boxes will involve a two-high stacking arrangement of the boxes. The rows of boxes will be separated by spacer blocks. The buffer boxes will be placed in a retreating arrangement within the placement room with any remaining voids in the rooms backfilled with GFM.

Placement rooms will be arranged in a series of panels that will be located on either side of the twin access tunnels. The panels of placement rooms will be located along repository arms that will extend from the Services Area. Figure 35 and Figure 36 show hypothetical layouts for the underground repository at the crystalline and sedimentary locations, respectively, where both layouts are based on disposal of 5.5 million fuel bundles. The overall repository layouts are adaptive and will be updated as the site investigations work proceeds.

Depending on the geologic conditions encountered, the underground repository will likely cover an area of about 2 km by 3 km (1,500 acres, 600 hectares). The repository in sedimentary rock will have a slightly larger footprint area than the crystalline rock because the sedimentary rock has a lower thermal conductivity. In order to meet maximum thermal design criteria, the spacing between UFCs within each room will be slightly larger which will lead to a slightly larger underground repository footprint in a sedimentary geosphere.

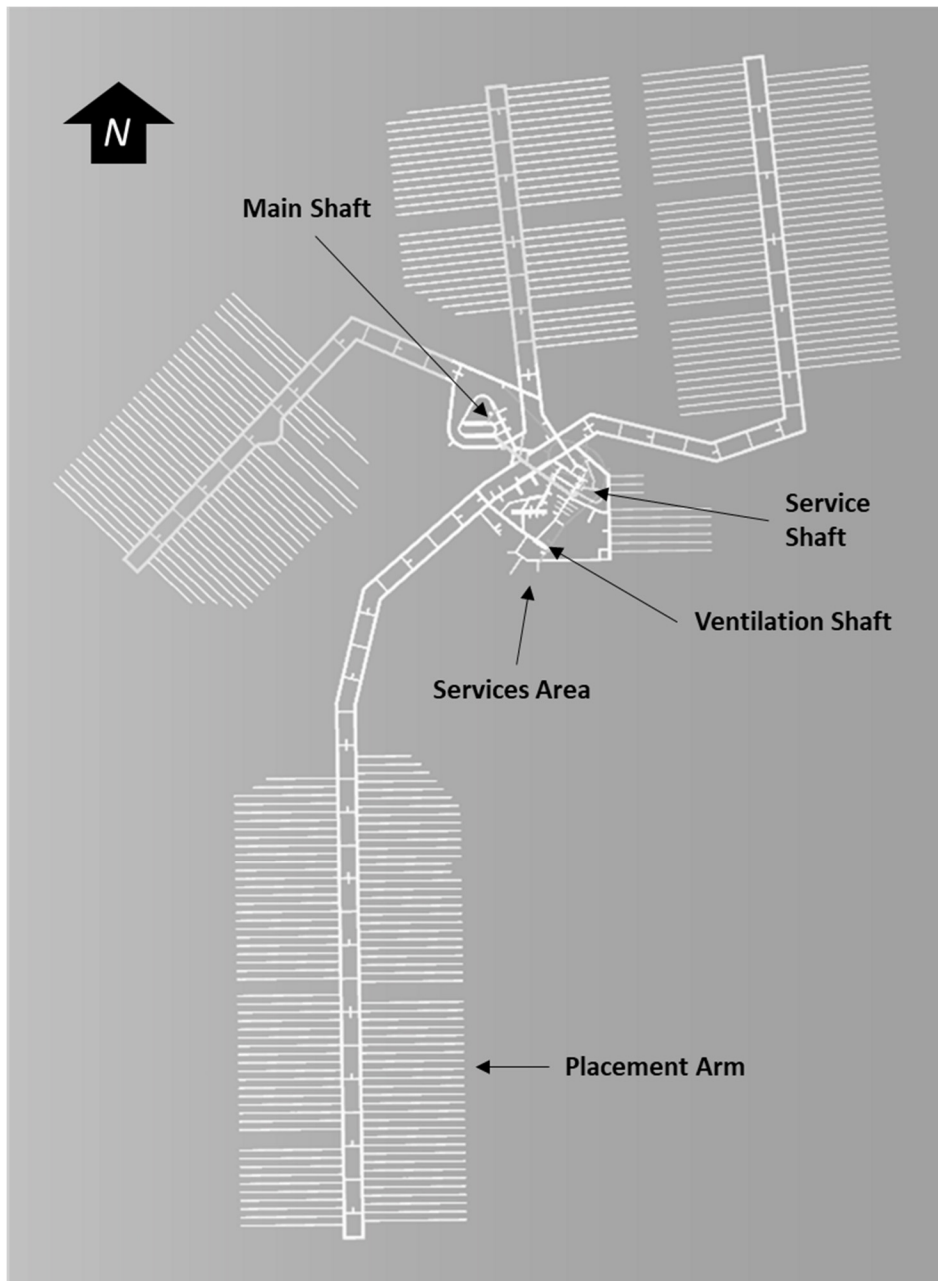


Figure 35: Repository Layout (Crystalline Rock)

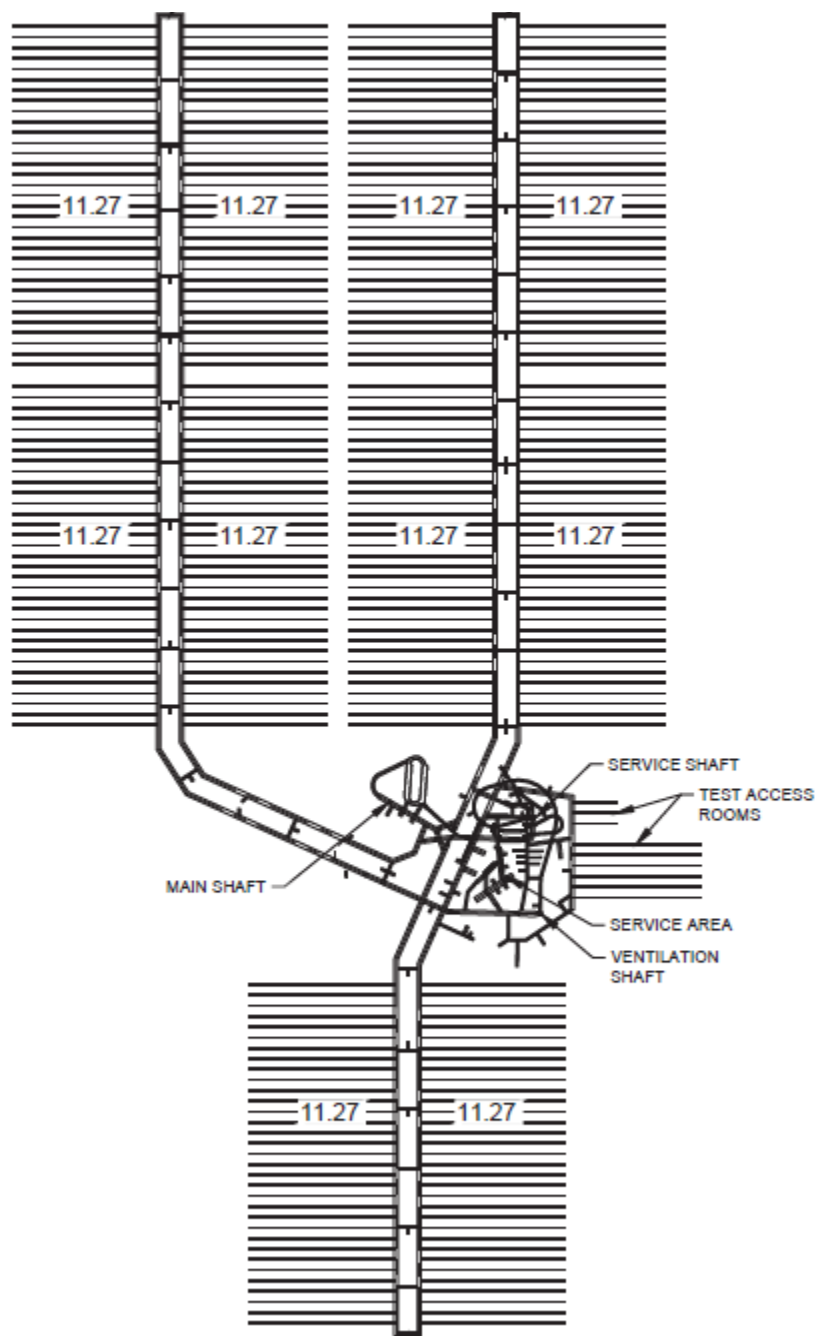


Figure 36: Repository Layout (Sedimentary Rock)

Three primary airways will be used to ventilate the repository. Service Shaft will constitute the dedicated fresh air passage and the Exhaust Ventilation Shaft and Main Shaft will constitute the exhaust air passages with the majority of air exhausting through the Exhaust Ventilation Shaft. A series of surface fans and underground booster fans will be required to achieve the design flow distribution in the underground repository. A surface-based fresh air heating plant will be used to heat air in winter months. Auxiliary fans and ducting will direct airflow into the placement rooms.

These aspects of the underground repository are described in the following sections, following a brief description of the expected geosphere conditions.

5.1 GEOSPHERE

The Ignace area in northwestern Ontario and the South Bruce area in southern Ontario are undergoing site investigations to determine suitability for hosting the DGR. The Ignace area is in a crystalline rock geosphere and the South Bruce area is in a sedimentary rock geosphere.

Site investigations have begun at the Ignace potential repository site and initial site-specific data as well as representative generic properties of crystalline rock are used to prepare a conceptual design for an underground repository at this site. Site investigations are just beginning at the potential repository site in South Bruce. At this stage, without site specific data, the conceptual design of the underground repository for this site is developed using data available from previous work done in the region.

5.1.1 Crystalline Rock Geosphere

Based on information available to date, the crystalline rock at the Ignace area location is expected to have favourable geoscientific characteristics for hosting a DGR. The geosphere is assumed to be an elastic, lithologically relatively homogeneous, and generally sparsely fractured rock. The rock at the depth range currently proposed for the planned repository, between 500 and approximately 800 m below ground surface, is assumed to be of a very good quality with mean permeability for the rock mass that is depth-dependent and ranges between $1 \times 10^{-19} \text{ m}^2$ (at 500 m) and $3 \times 10^{-20} \text{ m}^2$ (at 800 m), where the rock mass includes intact matrix and some amount of sparse fracturing.

The predominant rock encountered in the subsurface is a medium-grained igneous rock that varies compositionally between granodiorite and tonalite and with biotite as the characteristic mafic mineral, it is therefore identified as 'biotite granodiorite tonalite'. Between 84 % and 97 % of the total length of recovered core in each of the three deep boreholes completed to date is identified as biotite granodiorite tonalite. The mean intact uniaxial compressive strength of biotite granodiorite tonalite at the Ignace location, based on testing results to date, is 225 MPa. For design purposes, it has been assumed that approximately 10% of the volume of the repository rooms excavated would not be useable for UFC placement due to geotechnical conditions.

Fractures and fracture zones will be present in the rock mass. Fracture zones that are at least 500 m in length are modelled deterministically and represent layout determining features that are used to guide the development of a conceptual layout for the underground repository. Fractures and fracture zones that are less than 500 m in length are modelled stochastically using a geostatistical fracture propagation procedure. These smaller fractures and fracture zones are not considered to be layout determining features.

Water-bearing fractures and/or fracture zones will be present in a crystalline geosphere. If intersected by a placement room, groundwater may flow into the room. The location of placement rooms will be designed with a prescribed off-set distance from the deterministic fracture zones. Detailed site characterization will be used to define the distribution of the stochastic fracture network at the repository scale. During underground construction, investigations will continue with the drilling of pilot holes and probe holes at the excavation face of underground openings to continually refine our understanding of the fracture network at the placement room scale. If water or adverse conditions are identified, this new information will provide an opportunity to redesign or to take mitigating action such as grouting or abandoning a section of the placement room. The assumed likelihood of encountering sub-500 m long water-bearing fractures is why 10% of the room length is allowed for abandonment in the calculations for overall capacity of the underground repository.

5.1.2 Sedimentary Rock Geosphere

The sedimentary rock formation in Southern Ontario is comprised of layers of various types of sedimentary rock. At the South Bruce area location, it is assumed that the repository will be excavated within the Cobourg Formation, an approximately 30 m thick layer of argillaceous limestone located near the top of an approximately 190 m thick layer of good quality, low permeability, limestone. This thick sequence of limestone is overlain by an approximately 200 m thick layer of low permeability shale. Based on existing information from the surrounding region, the argillaceous limestone of the Cobourg Formation is assumed to be elastic, slightly anisotropic, laterally homogeneous, and sparsely fractured. The limestone rock is assumed to be a very good quality rock with a permeability of 10^{-21} m^2 (hydraulic property of the intact rock parallel to layering).

It is assumed that the Cobourg Formation is laterally continuous and homogeneous such that its geological characteristics, e.g., sparsely fractured nature, are transferable over large distances. For design purposes, it has been assumed that approximately 10% of the volume of the repository rooms excavated would not be useable for UFC placement due to geotechnical conditions.

Based on available information, a reasonable value for the mean intact uniaxial compressive strength of the Cobourg Formation, normal to bedding, at the South Bruce location is expected to be about 113 MPa.

Due to the low permeability of the limestone and presence of a thick low permeability shale formation above the host limestone formation it is expected that there will be very little groundwater inflow into the underground repository rock openings. The rock formations closer to ground surface will likely be more permeable.

5.2 UNDERGROUND DEMONSTRATION FACILITY

An Underground Demonstration Facility (UDF) will be constructed at the DGR site during the construction phase. Studies that would be conducted as part of the UDF include verification of geological conditions, demonstration of excavation and construction methods, validation of placement procedures for used fuel containers and sealing materials, long-term studies of engineered barrier materials or processes, and/or monitoring of specially instrumented emplaced containers.

This approach provides site-specific underground information, similar for example to POSIVA's Onkalo facility built at the Finnish repository site at Olkiluoto. It will build on prior knowledge obtained from the AECL Underground Research Laboratory in Pinawa, Manitoba, and from NWMO's participation in other underground facilities around the world in both sedimentary and crystalline rocks (Dixon et al., 2009; Kuzyk and Martino, 2008; Nagra, 2009; SKB, 2013).

The Underground Demonstration Facility (UDF) will be constructed as soon as possible after the Service Shaft reaches the shaft station and rock handling system is installed. The full UDF requirements have been split into two areas: 1) early UDF located between the Service Shaft and the Exhaust Ventilation Shaft and 2) main UDF which will be located to east of the Service Shaft and Exhaust Ventilation Shafts. Work in the early UDF would start when it is safe for the testing and demonstration personnel to enter this area.

The UDF will be constructed:

- To carry-out geoscience verification activities;
- To initiate and perform long-term sub-surface testing, monitoring and demonstration experiments;
- To demonstrate placement and retrieval of empty buffer boxes;
- To demonstrate rock excavation methods; and
- To practice the required safety culture and quality needed for facility construction and operations.

Table 15: Potential Experiments, Monitoring, and Demonstration Activities to be Conducted for Short & Long-term Safety

Programs	Locations	Duration
Rock Mass Characterization		
<ul style="list-style-type: none"> ➤ Geologic mapping of underground excavations ➤ Thermal property measurement ➤ In-situ stress state measurements ➤ Displacement monitoring (at underground openings) ➤ Seismic monitoring ➤ Geophysical monitoring 	Shafts, test rooms, and perimeter tunnels	Throughout initial construction (some tests continuing during operations)
Rock Mechanical Experiments		
<ul style="list-style-type: none"> ➤ 3D stress rotation experiment to support 3D modeling ➤ Large-scale rock strength tests ➤ Creep tests to determine the time and thermal dependent behaviour ➤ EDZ experiments around the underground spaces 	Test rooms and perimeter tunnels	During tunnel excavations and throughout initial construction and operations

Programs	Locations	Duration
Hydrogeological Experiments		
<ul style="list-style-type: none"> ➤ Straddle packer hydraulic testing of rock mass and fracture zones (if detected) ➤ Hydraulic interference and tracer transport experiments in detected fracture zones ➤ Monitoring of hydraulic pressures ➤ Characterization of EDZ from excavation and mining demonstration/optimization (see below) 	Boreholes from test rooms and perimeter tunnels	Throughout initial construction and operation
Geochemistry Experiments		
<ul style="list-style-type: none"> ➤ Long-term diffusion ➤ Radionuclide retention ➤ Microbial ➤ Monitoring of groundwater chemistry ➤ Matrix pore waters geochemistry 	Boreholes from test rooms and perimeter tunnels	Several years throughout initial construction and operation
Excavation and Mining Engineering		
<ul style="list-style-type: none"> ➤ Optimization of drill and blast techniques to minimize EDZ ➤ Optimal geometry / layout of placement rooms ➤ Long-term rock support performance ➤ Bulkhead Performance (including LHHP concrete interaction with bentonite bulkhead seal) ➤ Floor and wall smoothing experiments ➤ Grouting experiments 	Test rooms	Emphasis during first years of initial construction
Demonstration of Placement and Retrieval Equipment		
<ul style="list-style-type: none"> ➤ Radiation shielding and bentonite sealing systems ➤ UFC / buffer box placement trial ➤ UFC / buffer box retrieval demonstration 	Test rooms	Throughout initial construction and operation
Long-term Partial and Full-Scale Demonstrations		
<ul style="list-style-type: none"> ➤ Instrumentation and monitoring equipment ➤ Long-term degradation studies of sealing materials such as clays, clay mixtures, concretes and cements ➤ Long-term corrosion studies of container materials ➤ Performance of heated (empty) UFCs, bentonite sealing systems and near-field rock and groundwater ➤ Placement and long-term assessment of UFCs ➤ Retrieval of UFCs / buffer boxes with dedicated equipment ➤ Shaft, tunnel and room seals performance 	Test rooms	Throughout initial construction and operation

A rigorous verification and demonstration program would be carried out with possible areas of investigation listed in Table 15. After an overview description of the UDF, there is a further elaboration of selected programs in the following sections.

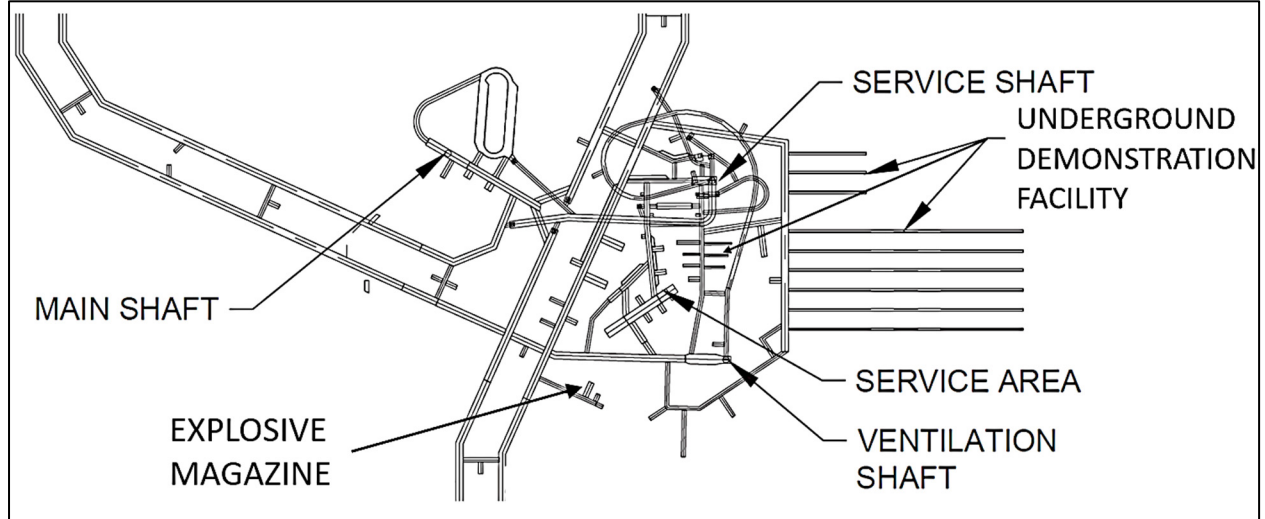


Figure 37: Underground Services Area showing Shaft and Underground Demonstration Facility locations

5.2.1 UDF Location and Configuration

The UDF will be designed to integrate with the overall underground repository but will be located to be separate from the repository placement rooms. This will ensure that facilities common to both the UDF and the repository are centrally located to both operations.

The UDF would be situated close to the Service Shaft and Ventilation Shaft Complexes as shown in Figure 37. The personnel offices and associated facilities will be located nearby. This area will be connected to the Shaft Complexes and other facilities through the access tunnels.

The proximity to the shafts will minimize the initial development required to place the UDF into operation. It will also minimize travel times and materials handling coordination during the initial room development. The technical staff involved in the experiments and demonstration work will have access to underground offices and specialized storage and repair facilities. These facilities will allow technical staff to undertake their support work close to where testing and demonstration work is being performed, thus reducing time in travel to and from the surface.

To simulate operating conditions as closely as possible, the test rooms would be designed and arranged so that their cross-sectional geometry and spacing are identical to that of the repository placement rooms.

The test room lengths would be designed to provide sufficient lateral area to allow setup of preliminary placement systems and their testing, and to accommodate any potential modifications as may be required while testing prototype equipment. In addition, the test room lengths are envisaged to incorporate sufficient space to allow for a production style operation of the finalized placement equipment configurations. This will ensure that the equipment systems can be successfully transferred from test to actual production conditions while also providing training to initial DGR crews in a near production mode environment.

5.2.2 UDF Life and Expandability

The UDF would be constructed during construction phase and would operate on a stand-alone basis for about 5 years prior to start of operations. The UDF would be developed to create a location to perform geotechnical and geoscience verification activities and to pre-test key aspects of the underground construction and operations. The UDF could continue to operate over the complete life of the repository, to demonstrate, monitor and confirm simulated UFC placement results and provide feedback on the effectiveness of the design approaches.

The underground repository's operational life is forecasted to be about 46 years, which translates into a 51-year life for the UDF. The additional 5 years, prior to start of operations, allows for test room development and the evaluation of various operational aspects of the underground works before UFC placement activities. It is possible that the UDF may operate longer than 51 years if it continues to operate in the extended monitoring period following the end of UFC placement activities.

5.2.3 Geoscience Verification Activities

Geoscience verification activities will be carried out in the UDF and at other locations in the underground repository for the purpose of verifying assumptions and geoscience data used in the safety case. In particular, data will be gathered to confirm that the host rock formation will be able to contain and isolate the used fuel. The results of these geoscience activities, among others, may be used in addressing any related licensing requirements during construction of the repository, and will be used to support the application for an operating licence.

Geoscience verification would also include investigations and monitoring activities to verify assumptions and geotechnical data used in the design of various underground openings. The data could be used to further optimize the design of various underground openings.

Geoscience verification activities at the repository level would begin upon completion of the Service Shaft and when a second egress is available. The characterization work will be performed in the area near the Main and Service Shafts and then progress into the UDF area. Characterization work would continue into the operations phase in various tunnels and placement rooms.

The data related to the baseline in-situ parameters such as rock strength, stress, temperature and permeability will require collection at an early stage of repository development to assess changes, if any, brought about by excavation activities. Measurement and the collection of representative samples for testing would, in part, be carried out through cored boreholes. Restriction on borehole location and orientation would be in place to mitigate the possibility of creating sub-surface pathways for groundwater and solute migration.

The excavation of the test rooms and the subsequent demonstration of placement and retrieval activities will impact the behaviour of the rock. Rock behaviour will be assessed by visual observation, physical measurement and geophysical techniques. For example, pre-installed stress cells, extensometers and inclinometers could be used to measure response of rock to excavation of test rooms. These same techniques could also be used to measure rock behaviour during access tunnel and placement room excavations and various other demonstration activities in the test rooms. Geophysical techniques such as seismic tomography and ground penetrating

radar could be employed to observe changes in properties inside the rock mass. Micro-seismic monitoring can also be used to assess the energy imparted by the various excavation techniques.

5.2.4 Long-term Testing, Monitoring and Demonstration Activities

Several long-term testing, monitoring and demonstration activities would be initiated during initial construction, and continue into the operations phase, with some monitoring expected to continue during the extended monitoring and closure phase.

Examples of long-term testing activities are, also identified in Table 15, are:

- Long-term diffusion experiments;
- Radionuclide retention experiments; and
- Seal materials compatibility tests.

Examples of long-term monitoring activities are listed below. These would include periodically checking of the physical conditions in the host rock and changes to those conditions, including:

- In-situ stress fields in the rock mass, and changes caused by excavation and heating;
- Groundwater pressure and chemistry, and changes caused by excavation and heating;
- Initiation, propagation and dilation of fractures, deformation or displacement of rock around openings, and changes in EDZ; and
- Rock temperature, and changes caused by excavation, ventilation and heating.

Examples of long-term demonstrations that could be conducted within the UDF or other niche areas:

- In-situ performance of heated (empty) UFCs and bentonite sealing systems;
- Placement and long-term assessment of active UFCs; and
- Performance of shaft and tunnel seals.

5.2.5 Demonstration of Placement and Retrieval of Used Fuel Containers

The UDF will provide an area prior to the start of operations for demonstration of various aspects of the eventual underground repository. The UDF will also be used for training operating personnel with mock-ups and actual equipment in a realistic environment. Some training areas could be employed to show visitors the operations of the underground works. Such interactions could be performed with little or no direct impact on the main repository's operation.

The UDF will also be used to test all aspects of the equipment and associated methodologies for UFC placement and retrieval. The evaluation work will be performed in a number of test rooms with each component of the placement or retrieval cycle undertaken in a location or room dedicated to that particular aspect of future activity.

The main aspects of placement room construction and operations to be tested, demonstrated, evaluated and refined would include:

- Placement room floor and wall leveling/smoothing, to reduce the need for fill materials;
- Buffer box and spacer block installations and stacking;
- Gap Fill Material (GFM) Backfill placements for room sealing;

- Use of remote-controlled equipment for various placement and backfilling operations;
- Construction of room seal and concrete bulkhead for room entrance sealing;
- Management of unsuitable volumes within a placement room and access tunnels due to fractures; and
- Retrieval demonstration.

Two rooms will be developed at the far end of the UDF for emplacement and monitoring tests. One room will have empty buffer boxes (without actual UFCs) to simulate buffer box installations. The second room will accommodate the placement of the buffer boxes with heaters that will simulate heat loading from used fuel inside UFCs (within buffer boxes). Data in the surrounding buffer and rock will be used to calibrate models that calculate the temperature, saturation and pressure conditions in the used fuel-filled underground repository. These two rooms will be isolated from the other test rooms to eliminate the possibility of any heating effect on local ground conditions and interfering with ongoing training or equipment testing being performed in the other rooms. Rooms will also be provided to demonstrate buffer installation in the placement rooms (HCB spacer blocks and GFM).

For these and other operational components, a demonstration room set-up will be established, and associated equipment installed. Following initial testing and monitoring in surface mock-ups settings, the operational components will be refined and improved with final testing carried out underground.

Testing will also focus on the potential automation and monitoring systems required for the underground operations. Test rooms will be provided with the same data, communication and automation support infrastructure that would be installed throughout the DGR facility.

Long-term performance demonstrations of UFC / buffer box, buffer, GFM backfill, sealing material(s) and geosphere over the period of operation of the DGR will be carried out. Tests will include dedicated demonstration rooms for monitoring the performance of both heated non-radioactive UFCs and UFCs containing fuel bundles. A component of this work will also examine the recovery of the buffer and backfill materials for geotechnical analysis, as well as the removal of the UFC / buffer box for corrosion assessments.

Placement methods for the UFC / buffer box will be assessed as well as the extraction/removal operations. UFC retrieval method will eventually be refined and perfected to encompass the removal of the concrete bulkhead, as well as the fully saturated sealing materials.

5.2.6 Demonstration of Excavation Methods

The test room excavation work will provide an opportunity to demonstrate and refine drilling and blasting techniques intended for the placement rooms. Grouting and other measures that are to be used to seal small local fractures will also be tested. In order to minimize potential pathways for groundwater movement after closure and to reduce the use of ground support in the placement rooms and tunnels, the blasting damage in the rock surrounding the created openings needs to be minimized and possible tolerances accordingly managed. This Excavation Damage Zone (EDZ) can be controlled through the use of careful excavation techniques. Detailed mapping of the rock after excavation, and correlation of the EDZ thickness to the blast-hole pattern and blasting techniques will ensure that the methods adopted meet all requirements. Excavation

methodologies for the various underground openings can, therefore, be optimized. Demonstration of quality requirements associated with excavation work will also be tested and optimized.

With respect to ground support, there are a number of options available depending on the rock conditions encountered. The UDF will allow testing of a variety of systems to optimize the approaches used for the different opening sizes and configurations. Where automated installation equipment (e.g., remote controlled rigs to install rock bolts) is deemed appropriate for quality control, such equipment would be tested and modified to meet the requirements of the DGR. If required, suitable experiments will be performed to demonstrate the process associated with removal of ground supports.

5.3 UNDERGROUND REPOSITORY LAYOUT

Conceptual layouts for the repository are illustrated in Figure 35 and Figure 36, for the crystalline and sedimentary rock geospheres, respectively. These layouts will change and be updated based on new information that is gathered from site investigations at the Ignace and South Bruce areas.

The operation of the DGR requires concurrent development, preparation, and placement of UFCs in the placement rooms. Separation of development (excavation) activities and Buffer Box / UFC placement activities will be achieved by ensuring that these activities occur in different repository arms. In the repository arm where UFC placement activities are occurring, non-nuclear equipment traffic and UFC delivery equipment traffic will follow dedicated and separate travel routes in twin access tunnels. In general, the excavation-related equipment and equipment carrying various non-nuclear materials (e.g., sealing materials and concrete) will travel in one access tunnel and the equipment carrying the UFCs will travel in the other access tunnel.

Placement room lengths are about 305 m in crystalline rock and 342 m in sedimentary rock geospheres which will reasonably accommodate development work by limiting ventilation ducting runs to practical lengths. These room lengths also allow the repository to be divided into a series of stand-alone panels with some flexibility in their location to avoid poor geosphere conditions, if encountered. As panel placement activities are completed, each placement room will be permanently sealed off with a room seal and concrete bulkhead.

The various components of the repository layout (access tunnels, services, placement rooms) are described in the following sections.

5.4 TUNNEL EXCAVATION PROFILES

The excavation profiles for the various tunnels and the ventilation raises have been based on equipment sizing and ventilation requirements.

Access Tunnels

Access tunnels will be developed with dimensions of 9 m wide by 4 m high (Figure 38). The width is determined to allow for the placement room entrance canopy and the forklift turning and positioning at the shield canopy.

As the access tunnels are developed, the main services will be installed including compressed air lines, waterlines, drain lines, power cables and ventilation ducting. After tunnel development has been completed the concrete floor will be established. The concrete floor will provide a smooth driving surface for buffer box handling equipment and will simplify any clean-up operations required. Lighting will be provided for the full length of operating access tunnels to improve visibility and safety.

These tunnels will also accommodate foot traffic without requiring safety bays for people. However, personnel on foot could stand in placement room entrances along the panel access tunnels to avoid passing mining equipment traffic during development, if necessary.

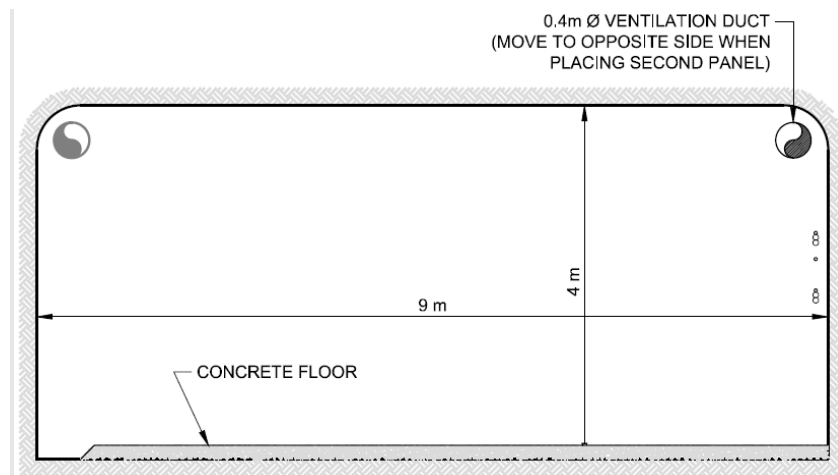


Figure 38: Access Tunnel Cross-Section

Ramps and Crosscuts

Ramps will be required in the Services Area to access the Fresh Air Transfer Level, and the Service and Exhaust Ventilation Shaft bottoms. Crosscuts will be excavated between the twin panel access tunnels about every 125 m. The crosscuts will be required to establish ventilation circuits in each placement room arm and to avoid the use of ducting to deliver ventilation air. The crosscuts will facilitate the separation of nuclear and non-nuclear traffic flow by allowing equipment to move between access tunnels. Crosscuts will allow personnel to move between access tunnels and to select the safest exit route during an emergency event. The crosscuts will be used to house electrical substations, refugee stations and drainage collection sumps.

The access ramps and crosscuts will be 5 m wide by 5 m high and are sized to fit the selected development equipment (Figure 39).

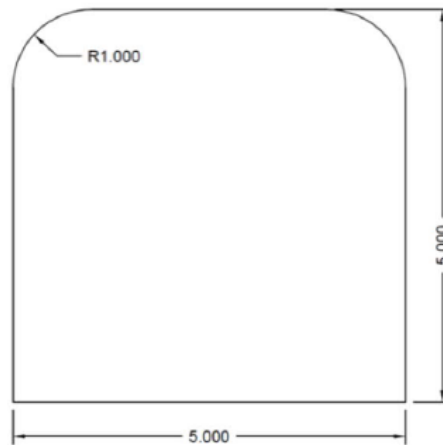


Figure 39: Ramps and Crosscuts Cross-Section

Fresh Air Transfer Level

The Fresh Air Transfer Level will be developed for distributing the intake air to each of the ventilation circuits without the need for ducting and airflow crossovers. The size of the tunnel is based on the planned airflow velocity at maximum rates (i.e., 6 m/s) to reduce the resistance factors and to ensure minimal entrainment of dust in the air. The fresh air delivery tunnels will be 9.0 m wide by 4.0 m high.

Ventilation Fresh and Return Air Raises

The fresh and return air raise sizes are based on the airflow velocity with the size for all based on the largest circular size of approximately 4.0 m diameter to allow common use of the excavation equipment. Raise boring could be the excavation methodology selected for these raises.

5.5 SUPPORT SERVICES AND INSTALLATIONS

Services and installations to support development of the underground repository, UDF and operations will be installed in their permanent configuration during the initial construction of the underground repository.

5.5.1 Support Services

The main support (utility) services to be provided for the underground operations are discussed below.

Electrical Distribution

Plant main 13.8 kV switchgear will supply power to underground infrastructure. One pair of 13.8 kV cables will be routed in the service shaft and another pair will be routed in the exhaust ventilation shaft. These two sets of 13.8 kV cables will distribute power to underground electrical

substations. The complete load can be carried by one pair of cables, providing 100% redundancy in capacity and alternate location. Electrical substations will step-down 13.8 kV to required 4.16 kV and 600V to feed relevant loads. The 600/208-120 V distribution transformers will provide power to miscellaneous loads including lighting and auxiliary power requirements.

Facility main 13.8 kV switchgear will supply power to different surface areas through a 13.8 kV power line. Each area equipped with 13.8/4.16 step-down transformer to feed 4.16 kV loads, 4.16/0.6 kV power distribution transformer to feed 600V loads, and 600/208-120 V distribution transformers to feed miscellaneous loads including lighting and auxiliary power requirement.

Compressed Air

Compressed air will be supplied by 3 compressors located on surface. One compressor will always be on standby while the other(s) are operating. This main supply line will be located in the Service Shaft and will connect to the underground distribution system piping. A back-up line will be in the Exhaust Ventilation Shaft.

Service and Potable Water

Underground service water will be required during both the construction and operation phases for mining equipment, dust suppression and various other services. Total annual underground service water requirements will be up to 47.3 million litres as noted in Section 3.10 during operations.

Underground potable water demand may be as high as 4 m³/day during both the construction and operation phases.

Service water will be sent underground in a pipe with a nominal diameter in the range of 80 to 200 mm pipe depending on quantity of service water to be delivered. The pipe will be located in the Service Shaft along with an equivalent redundant line in the Ventilation Shaft. These pipes will feed the distribution lines underground. Potable water will be sourced at the surface-based water treatment plant and delivered underground via pipe. Potable water will be supplied to all lunchrooms/refuge stations and washrooms via a separate underground potable water distribution system. Bottled water may also be used for the supply of drinking water.

Used service water will be collected in sumps and pumped to surface settling ponds as noted below.

Mine Dewatering

Used service water and potable water, as well as, any underground water inflows will be collected and ultimately be sent to the main sump where the water will be pumped to surface. All water pumped to surface will be cleaned of particulate matter in the surface-based mine dewatering settling pond before discharge to a receiving water body.

The main sump will be located in the Service Area and additional sumps will be located as needed in the main repository footprint. Pumps placed in the sumps and dewatering lines will direct water to the main sump, for settling, recirculation and/or discharge from the mine. All sumps would be periodically cleaned to remove settled sediments.

Mine Communications and Controls System

A communications and data network will provide voice communications, Programmable Logic Control (PLC) monitoring and control, data collection and dissemination via an underground computer LAN and video. A fibre optic cable backbone and wireless data and voice system will provide all applications required to operate the mine and undertake data handling and transmission to the surface.

5.5.2 Primary Support Facilities

The key primary facilities that will be needed to support development and operation of the underground repository are discussed below. Additional support facilities not discussed below will also be in place (e.g., Buffer Box / UFC temporary storage area, parking areas, etc.).

Mobile Equipment Shop

A shop will be in place to perform all maintenance on the mobile equipment such as mining equipment, service vehicles and personnel carriers. This shop will be located relatively close to the Exhaust Ventilation Shaft and will have a main shop area for working on larger equipment and satellite bays to service smaller equipment. It will also incorporate a wash bay, welding shop, parts storage warehouse, electrical room, lunchroom and a supervisors' office. All workstations will be connected to the communication system. Details of the proposed maintenance shop arrangement are presented in Figure 40.

The main shop area will be approximately 50 m long, 12 m wide and 10 m high. Overhead bridge cranes and an overhead monorail crane will be in place to support the maintenance activities.

Lube Bay

A lube bay will be constructed near the mobile equipment shop. It will be provided with a fire-resistant roll-up door at the open end to separate the lube bay from other working areas in an event of a fire. The lube bay will house three high-density polyethylene (HDPE) lube tanks.

Charging Stations

Space has been allocated for parking and battery charging along the mobile equipment shop access tunnel and in the Services Area associated with unit parking. In addition, there is provision of a parking and charging station in the Main Shaft Station for the UFC/Buffer Box transfer cask tow vehicle. The battery-powered emplacement vehicles to be used in the placement rooms will have their batteries recharged at the placement room entrance area.

It is assumed that all equipment will be battery-powered both during construction and operations phases. Thus, there would not be a need for an underground diesel fueling station. Should a future decision be made to operate some diesel-powered equipment the diesel fuel would be supplied at a station located near the mobile equipment shop.

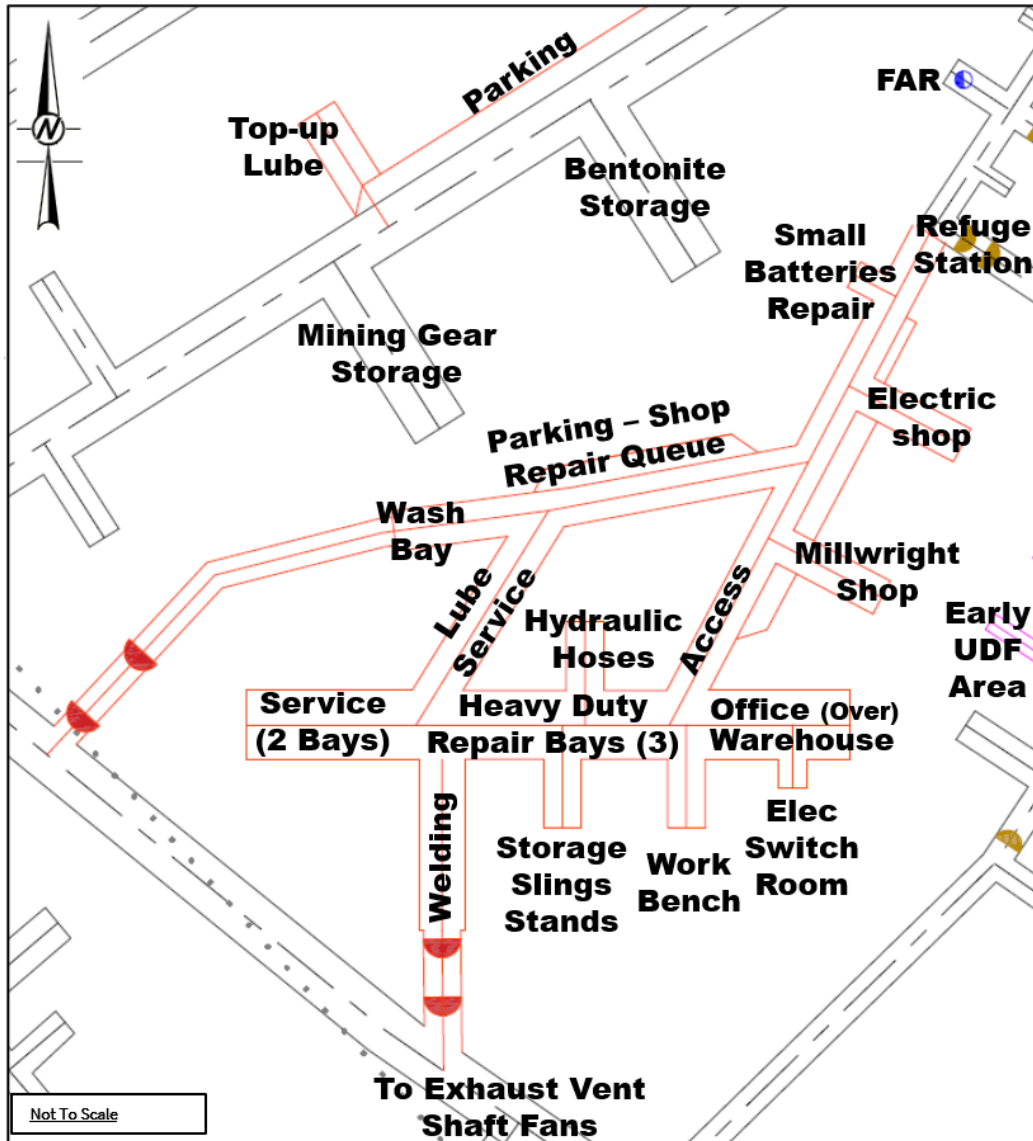


Figure 40: Maintenance Shop

Explosives Magazine

An explosives magazine will be located away from the Services Area and the panels of placement rooms, as shown in Figure 37, following best practice. However, it will be readily accessible for mobile explosives loading trucks. The magazine will be fitted with shelving for bulk explosives bags and stick powder and equipped with a wall mounted jib crane.

Detonator Magazine

The detonator magazine will be located nearby to the explosives magazine but separated by a distance of at least 8 m. It will be equipped with shelving for the stacking of detonator boxes.

Materials Handling and Storage Areas

A storage area for mining consumables including pipes and fittings, ground support materials, ventilation supplies, etc. will be developed along the Services Area east access tunnel. With a 20 m length, 7 m width and 5 m height, the area will include shelving and racking to safely store mining consumables.

A storage area will be developed along the Services Area east access tunnel for bentonite materials. Rubber-tired vehicles will transport bulk shipments from the Service Shaft to this temporary storage area.

Rock Dump and Rock Breaker

Excavated rock will be delivered to the rock dump by haul trucks. Prior to delivery this rock will be sent down to the loading pocket near the base of the Service Shaft, where it will be reduced in size, as required, by the rock breaker. Broken rock will be loaded into a skip at the loading pocket for delivery to surface and, ultimately, to the excavated rock management area.

5.5.3 Ancillary Support Facilities

The Services Area will include ancillary facilities for technical staff. Such facilities will include offices, specialized equipment repair areas, washrooms and combination refuge stations or lunchrooms (where, in the event of a fire or other emergency, personnel would gather for safety). A tunnel near the Main Shaft will provide access to most of these facilities.

Offices/Lunchroom

The offices, with lunchroom area, is a dedicated facility for this purpose. Offices will be provided with a computer network connection to the DGR-facility-wide data and control network.

Refuge Station

A large permanent refuge station will be established in the Services Area and will only be used as safe refuge for workers and visitors in the event of an emergency (i.e., will not be used as a lunchroom or for office space). The station will be located between two access tunnels which will allow access at either end of the station. The station will have 2 concrete walls with steel doors in the wall at each entrance to the refuge station. They will include a main area for personnel, and an operations supervisor's office at the back end of the station. The refuge station will be equipped with safety and rescue equipment such as a fire extinguisher, eyewash station, first aid kit, emergency food and drink rations and stretchers. The refuge station will provide a location that can be sealed and will be supplied with fresh air via the compressed air system. The piping network supplying breathing air to the refuge station will be designed to be in pressurized state (always ready to use) although breathing air will only be required during emergencies. All breathing air supplied to a refuge station will pass through an air purifier unit, which will be located underground inside the refuge station.

Portable Refuge Stations

A portable refuge station will be placed underground in each arm of the repository within crosscuts that connect the twin access tunnels in each arm. These portable refuge stations will provide

refuge to workers and visitors during an abnormal event when safe passage to the permanent refuge station in Services Area is not possible. Each of the portable refuge stations will contain bottled compressed air for emergency breathing air. Alternatively, the portable refuge stations could use a Refuge One Air Centre (e.g., oxygen generator) to supply breathing air. The portable refuge station will also have a stock of bottled drinking water for the occupants.

Washrooms

Underground toilets (portable mining toilets) will be provided near the offices and refuge station. Wastewater from the washrooms will initially be held in local holding tanks. These tanks would be pumped out on an as-required basis to a larger transport tank for transmission to the surface for treatment. During the subsequent development of the underground repository, additional portable toilets will be provided, as needed, near working areas.

Instrumentation Shop

An underground instrumentation shop will be provided across from the offices to store and repair specialized equipment used in testing activities. The shop will be approximately 30 m long by 5 m wide and 4 m high. It will be equipped with work benches, shelving and repair and calibration tools. Other storage areas for specialized tools and parts used in the UDF testing rooms will be developed near the aforementioned rooms.

Special Equipment Storage

The special equipment storage area will be used for the storage of special equipment to be used for either testing or monitoring in the UDF or elsewhere in the underground repository. The area would have climate control to protect the equipment while in storage.

Temporary UFC/Buffer Box Transfer Cask Storage

There are two rooms that will be used for the temporary storage of transfer casks. If a placement room is not ready to receive a transfer cask with buffer box, then the cask could be taken to these areas for temporary storage. Similarly, empty transfer casks could be stored in one of these rooms while awaiting delivery back to surface via the Main Shaft.

5.6 PLACEMENT ROOMS

Each placement room will be dead ended. A nominal rectangular room section geometry has been adopted with a vertical height of approximately 2.4 m and a room width of 3.2 m. This is illustrated on Figure 41 and Figure 42 which shows a placed buffer box (with UFC) as well as the clay-based sealing components in crystalline and sedimentary geospheres respectively.

5.6.1 Placement Room Arrangements

Within the placement rooms, the buffer boxes will be stacked two high, separated by HCB spacer blocks (the approximate thickness of 0.3 m for crystalline and 0.7 m for sedimentary). GFM would be used to fill any remaining voids after placement. Following the completion of buffer box

placement within a particular room, it will be sealed with additional bentonite and a concrete bulkhead (plug).

The placement density of the buffer boxes (with UFCs) is designed to minimize the areal extent of the DGR, while satisfying established design parameters including heat dissipation and structural integrity. The actual configuration will be a function of the characteristics of the rock mass, and particularly the accommodation of any structural discontinuities or other geological features that may be encountered during development.

Placement room lengths will be based on the assumption that 10% of the buffer box positions will be rejected. Rejection will be due to unacceptable groundwater seepage ingress or other unsuitable rock conditions encountered in the placement room. As approximately 10 buffer boxes will be placed per day, at least 3 placement rooms will be required to be available for placement activities.

Prior to the buffer box placements, the full length of the placement room will be prepared by first placing a smooth levelling layer consisting of granular material that will be topped with a thin layer of concrete. 150-mm-thick bentonite floor tablets will then be placed on the levelling layer on which the Buffer Boxes will be stacked.

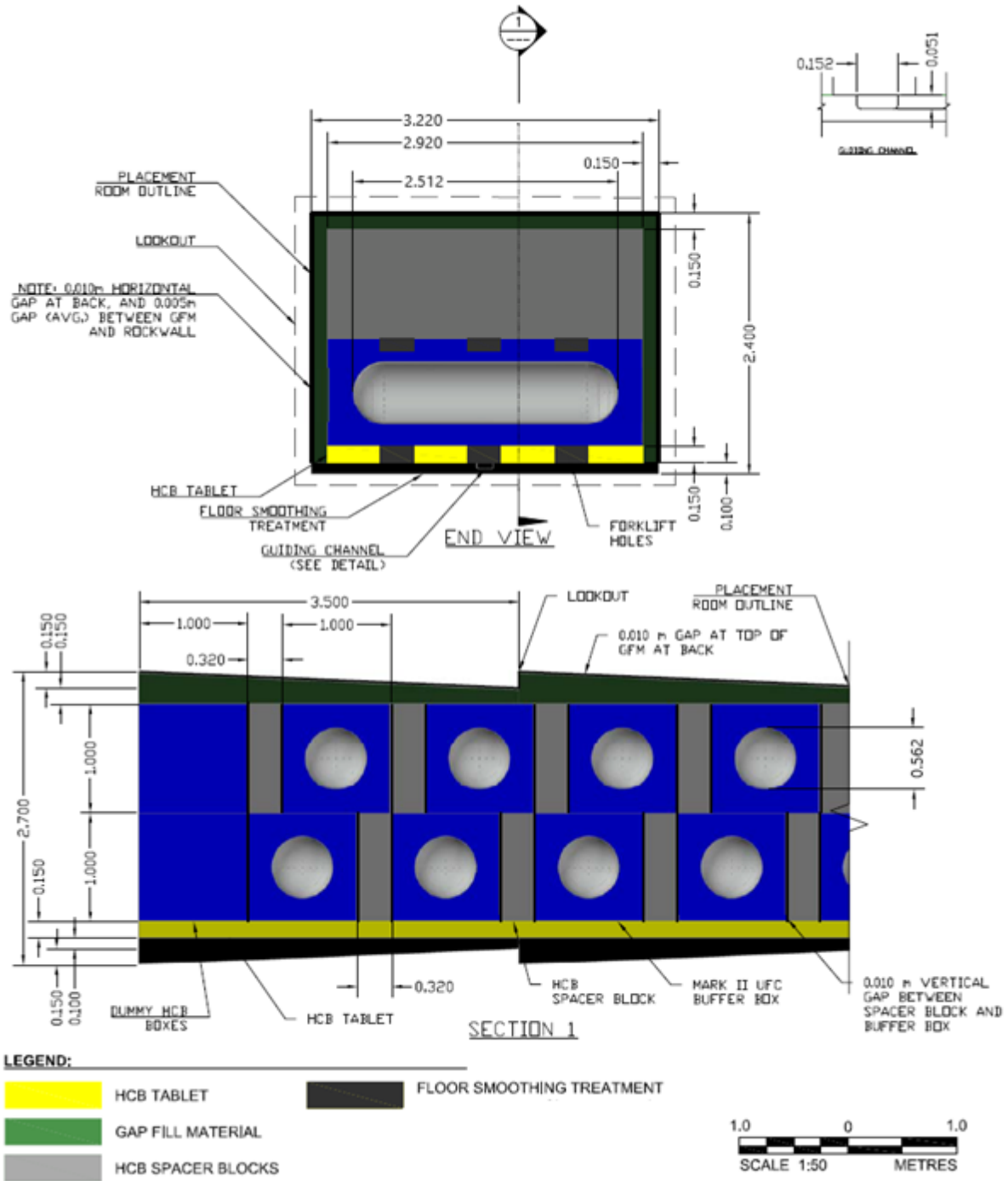


Figure 41: APM Placement Room Cross-Section View (Crystalline Geosphere)

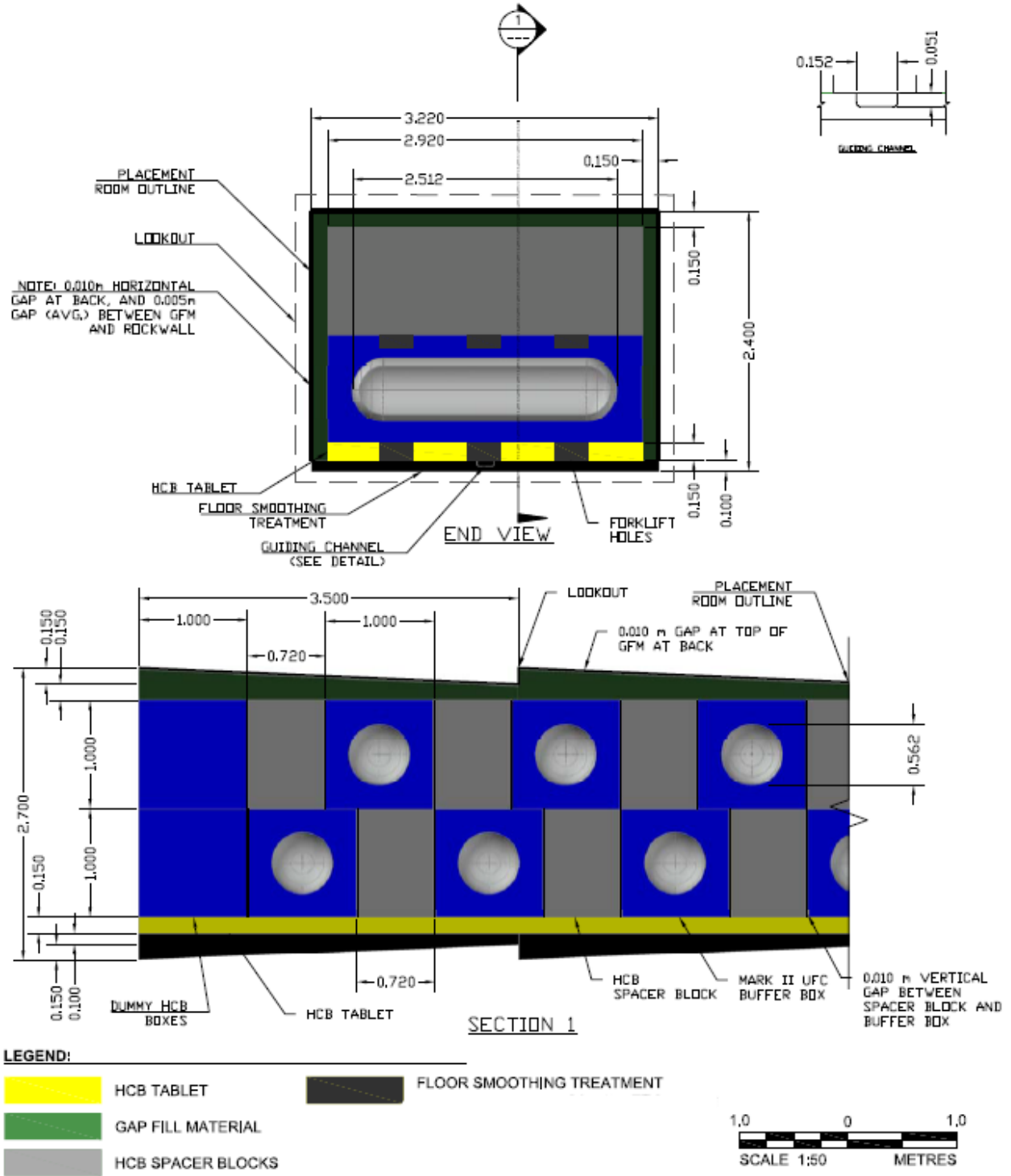


Figure 42: APM Placement Room Cross-Section View (Sedimentary Geosphere)

5.6.2 Placement Room Geometry

A nominally rectangular room cross-section will be adopted to minimize the amount of bentonite GFM required to fill the void space surrounding the stack of buffer boxes. A room cross-sectional dimension of 3.2 m wide by 2.4 m high was chosen which will allow buffer boxes to be stacked two high (see Figure 41 and Figure 42). This room geometry will be sufficiently large to permit access for the mining equipment and the buffer box placement equipment.

The repository host geosphere is expected to comprise a good quality rock with high strength and moderate in-situ stresses. The axis of the placement room will be oriented parallel, as far as practical, to the major principal stress orientation. This configuration will minimize stress concentrations about the perimeter of the placement room.

When designing the placement room geometry and the general arrangement of the placement rooms, possible rock loadings due to glaciation and/or a large earthquake event will be considered.

5.6.3 Buffer Box and Placement Room Spacing

Heat will be generated by the UFCs. Such heat and the resulting elevated thermal regime must be evaluated with respect to the requirement that temperature on UFC surfaces must be below 100°C at all times. The surface temperature of the used fuel container must be maintained below 100°C to ensure that the properties of the surrounding bentonite and the copper are not adversely affected. At elevated temperatures (~140°C), the bentonite begins to convert to illite, a non-swelling clay. These physical changes are irreversible and leads to uncertainty for the long-term performance of the placement room. At temperatures above 125°C the electrochemical behaviour of the copper changes and more rapid corrosion may be possible.

To ensure temperature will not exceed 100°C on surface of UFCs, the center-to-center spacing of the buffer boxes will be set at approximately 1.3 m for crystalline rock or 1.7 m for sedimentary rock. In addition, the center-to-center spacing of placement rooms will be set at 25 m for both crystalline and sedimentary rock geospheres.

5.6.4 Above Ground Emplacement Demonstration

An above ground demonstration in a simulated emplacement room (mock-up) will be performed in 2022 to demonstrate specific unique technologies associated with the in-room emplacement. The mock-up full-scale emplacement room structure is metal framed with faux rock panels to simulate the drill and blast profile that could be expected in the underground, as shown in Figure 44.

The demonstration trial will integrate all the bentonite technology development into one complete demonstration. The first-of-a-kind technologies that will be demonstrated during this trial include:

- HCB consolidation from bentonite powder;
- Gap fill production from bentonite powder;
- Highly compacted bentonite block shaping;
- Temporary storage of the bentonite block after shaping;
- Assembly of the Buffer Boxes with completed HCB blocks using vacuum lifts;

- Placement of Buffer Box with semi-autonomous emplacement equipment (Figure 43);
- Gap fill emplacement with Auger system; and
- 3D scanning of the emplacement room before and after emplacement to confirm placed density.

Upon completion of the trial, the mock-up emplacement room will be inspected to quantitatively and qualitatively assess the achieved result. The demonstration trial will be an operational demonstration to gain confidence in the prototype technology development.



Figure 43: Prototype Buffer Box Emplacement Equipment



Figure 44: Prototype Emplacement Equipment entering the Mock-up Full-scale Emplacement Room

5.7 DEVELOPMENT OF UNDERGROUND REPOSITORY

5.7.1 Drill and Blast Excavation

Drill and blast method will be selected for excavating underground openings because this method can easily be adapted to a range of rock conditions and customized tunnel shapes. The blasting designs can be readily accommodated to meet particular requirements. Further, the technology is mature and efficient. All drill and blast underground excavations will be undertaken using rubber-tired mining equipment.

Blasting operations will include drilling holes in a converging pattern, placing an explosive and detonator in each hole, detonating the charge, and removing or excavating the excavated rock. The blasthole patterns will be selected to minimize the quantity of explosive detonated per volume of rock broken. Blastholes will be typically detonated in sequence from the center of the excavation outwards with each detonation creating an open face for the next volume of rock to break towards.

Between the blasting cycles, fumes will be vented, scaling will be undertaken to remove loose rock, ground support will be installed as required, and the next round of blasting will be surveyed. Typical standard drill and blast practices result in a rate of advance in the range of 5 m to 15 m per day based on one crew working multiple headings.

All underground excavations will be excavated by using controlled drilling and blasting techniques. Conventional drilling and blasting in normal mining environments inherently create a damaged zone in proximity to the opening. A controlled drill and blast method will be used to minimize the EDZ and thus, the zone of potentially enhanced permeability at the perimeter of the underground openings. Under a controlled drill and blast approach, a closely spaced series of perimeter holes will be established around all sides of the opening. Computer-assisted drill jumbos will be used to ensure accuracy of perimeter drill hole locations. The perimeter drill holes will be loaded with decoupled low impact explosives and these holes will be blasted last. The blasting of these holes will also be timed to ensure that ground movement is minimized in the walls and that minimum energy transfers from the main development round and perimeter hole blasting to the surrounding wall. Electronic blast initiators can also be utilized to provide maximum accuracy in blasthole initiation.

5.7.2 Rock Support Requirements

It is assumed that there will be good quality rock in both the crystalline and sedimentary rock geospheres. Thus, it is expected that no rock support will be required in small rock openings (i.e., spans less than 5 m). However, to meet health and safety requirements, an appropriate rock support system will be installed in the Services Area openings and access tunnels, as these are permanent working areas. In zones of poorer rock conditions, additional rock support will be applied as required.

After the broken rock will be removed from the various openings in the Service Area and the various tunnels, a scissor-bolter-screener unit would be used to install ground support. The roof and walls will be first secured with rock bolts and later with fibre-reinforced shotcrete. For the access tunnels with a 9 m span, it is assumed systematic bolting will be installed on a pattern of 2.5 m x 2.5 m spacing. Patterned bolting will also be required at the intersections of all tunnels.

Due to expected good quality rock of the host geosphere (crystalline or sedimentary), it is likely that no ground support will be needed from a geotechnical standpoint within the tunnels with a span of less than 5 m and in the 3.2 m-wide placement rooms. However, prior to underground construction and development, appropriate ground support requirements will be developed through more detailed geotechnical investigation and health and safety requirements.

Where the development and placement rooms cross zones of poorer ground, additional support will be applied as required. It has been assumed that 10% of the tunnel lengths will require additional support based on encountered conditions.

Due to the long life of the repository, a monitoring program will be implemented to assess the long-term performance of the established ground support features. Maintenance or installation of additional support will be carried out as required.

Note: The above support recommendations are preliminary and illustrative only. Rock support systems will need to be revisited after geotechnical characterization is performed at the preferred location.

5.7.3 Development Schedule

Construction Phase

Once the sinking and equipping of the shafts is completed, they will be utilized to develop the Service Area including the UDF. The sumps and main electrical substation will be completed first to support on-going development. Development of the other support facilities in the Service Area (e.g., mobile equipment shop, charging station, explosives magazines, etc.) will follow. With the underground infrastructure in place, the UDF and all twin access tunnels will be developed into the placement area from the Services Area.

Placement rooms will be excavated at the boundaries of each panel (called panel boundary rooms). The two rooms will be excavated to confirm the suitability of rock for hosting placement rooms. The one full panel of placement rooms would be established during construction phase and before the DGR facility is commissioned.

Services (compressed air, water, electrical, etc.) will be extended along twin access tunnels as appropriate to support activities along repository arms. A preliminary underground layout for the crystalline geosphere at the end of the Construction Phase is shown in Figure 45.

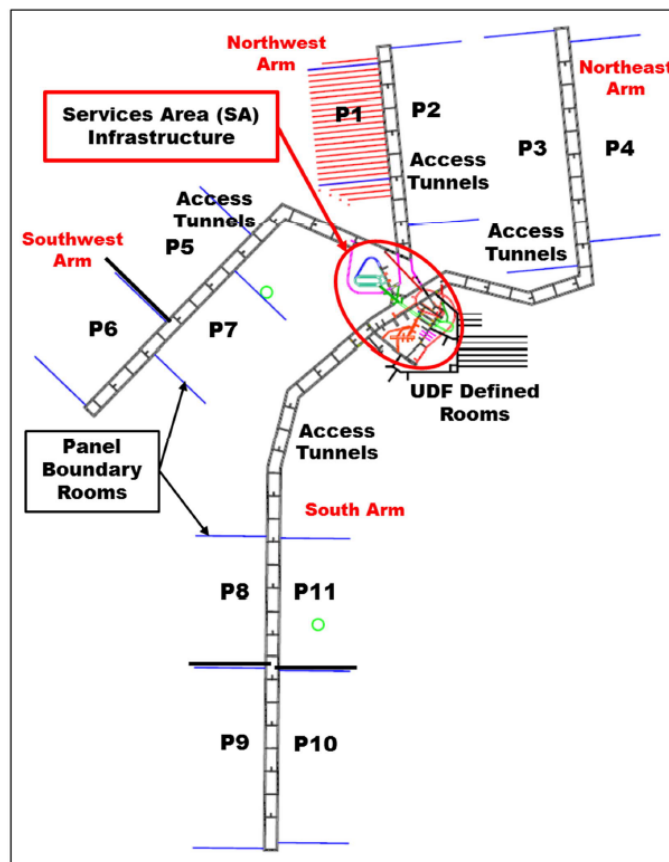


Figure 45: Underground Development during the Construction Phase (Crystalline Geosphere)

Operations Phase

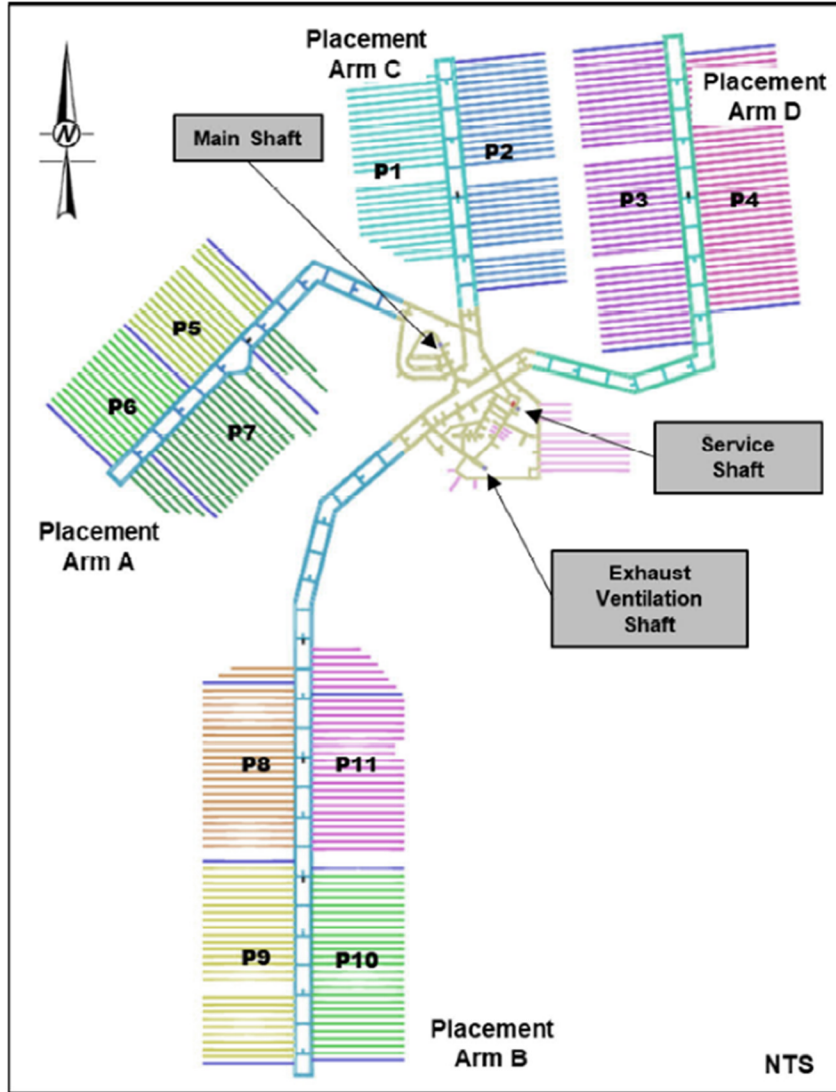
During the operations phase, there will be concurrent construction and placement activities. That is, buffer boxes will be placed in placement rooms at the same time as additional placement rooms are being excavated. However, excavation and placement activities will be isolated from one another so that excavation and placement equipment do not operate in the same repository panel simultaneously.

Each placement panel will be completed in its entirety before commencing to the next panel so that panel development will be completed prior to placement operations and to ensure that excavation and placement activities will be isolated from one another. When possible, excavation activities will be concentrated in one repository arm while placement activities will be performed in another repository arm. This will ensure that secondary vibration of already developed placement rooms, where placement activities are taking place, will be minimized until the finished rooms are backfilled and sealed.

The sequence outlined in Figure 46 also illustrates the separation of activities for the crystalline geosphere. Each placement panel in the DGR would require approximately 3 to 5 years for development. Buffer box UFC placement activities within the panel of rooms would require 3 to 6 years. Because of the requirement to have one panel completed before placement activities start, the development activities that occur during operations will end about ten years earlier than the placement activities.

Traffic Flow

The Service Shaft and associated underground shaft station area will generally only receive mining and construction equipment traffic or equipment handling sealing materials and other non-nuclear materials. Main Shaft and associated underground shaft station area will generally only receive Buffer box UFC handling equipment (i.e., will be "controlled areas"). Mining and construction equipment as well as non-nuclear material handling equipment traffic will travel along routes that are separate from routes used by the Buffer Box UFC handling equipment.



Panel #	Development		Placement	
	Start Date	Finish Date	Start Date	Finish Date
Panel 1	Feb-40	Nov-42	Jul-43	Mar-47
Panel 2	Jun-57	Jul-60	Jun-61	Feb-66
Panel 3	Jul-43	Apr-47	Apr-47	Jun-53
Panel 4	May-61	Nov-64	Jan-66	Nov-71
Panel 5	Sep-71	Sep-74	Jan-76	Sep-78
Panel 6	Apr-79	Apr-82	Oct-83	Apr-86
Panel 7	Apr-53	Feb-56	Jul-57	Jul-61
Panel 8	Sep-83	May-86	May-86	May-90
Panel 9	Dec-75	Apr-79	May-79	Nov-83
Panel 10	Dec-65	Sep-70	Oct-71	Feb-76
Panel 11	Apr-47	Apr-52	May-53	Aug-57

Figure 46: Example Sequencing of Development and UFC Placement Activities (Crystalline Geosphere)

5.7.4 Material Handling

Rock Handling

Broken rock will be loaded into the underground haul trucks at the placement room entrances. Loaded trucks will travel along the access tunnels to the truck dump near the Service Shaft. The trucks will unload their broken rock load onto a grizzly at the dump. A hydraulic rockbreaker would break any oversize rock left on the grizzly. The rockbreaker will be automated to allow remote operation by the skip tender or by a central control room operator. Material from the dump will flow to the loading pocket level for skipping to surface in the Service Shaft.

Materials Handling

Materials for development (e.g., explosives, rock bolts, pipe, etc.) will be transported on rubber-tired service vehicles in the Service Shaft and moved to the main storage area. The vehicles will be off-loaded, and materials placed in the main storage area. Similar service vehicles will carry materials from the main storage area to working places throughout the underground development.

5.7.5 Equipment Requirements

The underground repository will be developed by utilizing rubber-tired battery-powered equipment.

Buffer boxes will be transferred to the underground repository using the Main Shaft. All personnel, equipment and development muck will be transported using the Service Shaft (see Section 4). Placement equipment consists of a customized vehicle to handle the buffer boxes in the placement rooms and a tow vehicle and trolley to move the transfer casks (loaded with buffer boxes) from the shaft to the placement rooms.

A preliminary list of mining equipment and quantities for both the initial construction of the underground repository and for on-going development during the subsequent operations phase is presented in Table 16.

Table 16: Generic Underground Mobile Equipment List

Equipment Types	
Load-Haul-Dump (LHD) Loaders	Grader
32 tonne Trucks	Service & Crew Trucks
Development Jumbos	Boom Truck
Scissor Bolter	Bucket forklifts
Scissor Lift	Utility Vehicles
ANFO Loader	Miller Carts
Shotcrete Truck	Service Trade Vehicles
Concrete Truck	

In all, the following concepts for underground equipment will be applied:

- All underground excavations will be carried out by rubber-tired equipment (jumbo's, Load Haul Dump (LHD) machinery and trucks);
- Rubber-tired equipment will be propelled by battery-powered motors. Semi-stationary equipment such as drill jumbos will be powered by electricity;
- Haulage of development rock to the shaft will be by battery-powered trucks;
- Transfer of buffer boxes (with UFCs) on trolleys to entrances of placement rooms and trolleys will be moved by rubber-tired tow vehicles;
- Activities inside placement rooms receiving buffer boxes will be carried out by battery-powered machinery; and
- The routing and scheduling of panel development and buffer box placement activities will be separated, with dedicated routes for each.

5.8 SUBSURFACE VENTILATION

Three primary airways will be used to ventilate the repository. The Service Shaft will constitute a dedicated fresh air passage. The primary exhaust air passage will be via the Exhaust Ventilation Shaft and a relatively small amount of air will exhaust via the Main Shaft. A series of surface fans and underground booster fans will be required to achieve the design air flow distribution in the underground repository. A surface-based fresh air heating plant will be used to heat air in winter months. Auxiliary fans and ducting that are located in the underground tunnels and rooms will direct airflow into active placement rooms.

Network modelling techniques (e.g., Ventsim software) were used to create a three-dimensional representation of the ventilation system, and to conduct ventilation simulations for the excavation and placement activities. Based on the results of modeling the primary surface fans, underground booster fans and the associated distribution ducting were sized.

Independent ventilation circuits will be established for the placement and excavation areas of the underground repository. To the degree possible, the system will be set up to ensure that underground work would be performed in a fresh air supply stream with the exhaust being directed through unoccupied areas (low contamination areas to higher contamination areas). Ventilation requirements are based on providing dilution of excavation contaminants and dissipation of heat to provide a comfortable working environment.

5.8.1 General Description of Ventilation System

The system will use three vertical shafts and a combination of parallel airways to intake and exhaust the air from surface through the underground facility and back to surface (see Figure 47). The system will make use of underground booster fans, auxiliary fans, ventilation doors, and regulators to control airflow distribution and ensure a 'one-pass' ventilation system.

The main repository ventilation system conduits (panel access tunnels) will provide relatively large airways. The overall circuit, including the shafts, can be described as a system with relatively low airflow resistance characteristics.

The primary ventilation network consists of a push-pull type system. At the Service Shaft, the two surface fans (three fans including an installed spare) will force fresh air through the surface plenum and into the shaft area (a small amount will be upcast in winter months through the shaft

headgear to prevent freezing). Underground booster fans are then envisaged to take-over within the shaft system and pressurize the underground operation to allow for a positive pressure distribution in the repository. Ventilation control doors, booster fans, auxiliary fans and regulators will be used to direct and control the quantity of fresh air.

Fresh air will be routed into the Service Area to ventilate the mobile equipment shop, main electrical sub-station, main sump, storage areas, offices and shops before being discharged into the Exhaust Ventilation Shaft (see Figure 48). Exhaust air from the Service Area will be routed to the Exhaust Ventilation Shaft by two underground booster fans. The return air will then be exhausted to surface via a plenum which leads to 15 m-high ventilation stack that is located close to Exhaust Ventilation Shaft headframe. A small quantity air will be exhausted from the underground cask storage area up the Main Shaft. At surface the air will exhaust to surface via a plenum which leads to 9 m-high ventilation stack that is located close to Main Shaft headframe.

Air will be distributed throughout the underground repository through the use of ventilation doors, regulators and fans. Within a given repository arm, fresh air will be supplied via one of the twin access tunnels and exhausted through the other access tunnel. Fresh air will be delivered into individual placement rooms through auxiliary fans and duct systems. Exhaust air from repository arms would be routed to the Exhaust Ventilation Shaft by two underground exhaust booster fans and then directed to surface via the Exhaust Ventilation Shaft Complex.

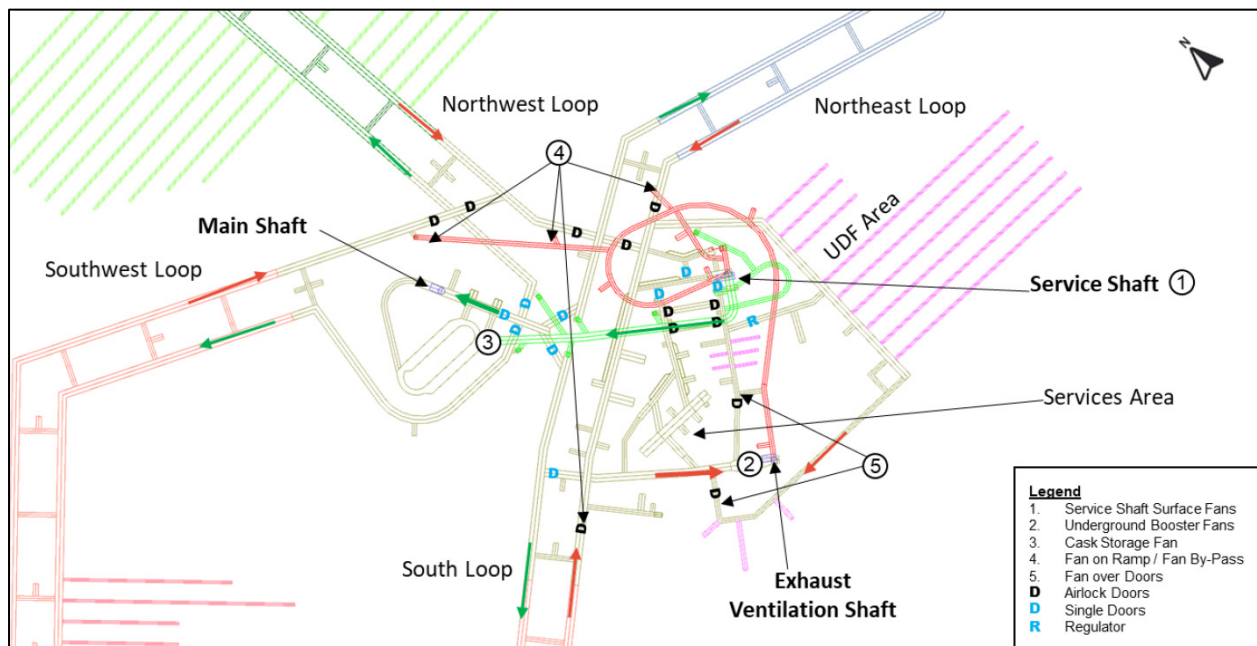


Figure 47: Ventilation Infrastructure for the Crystalline Repository

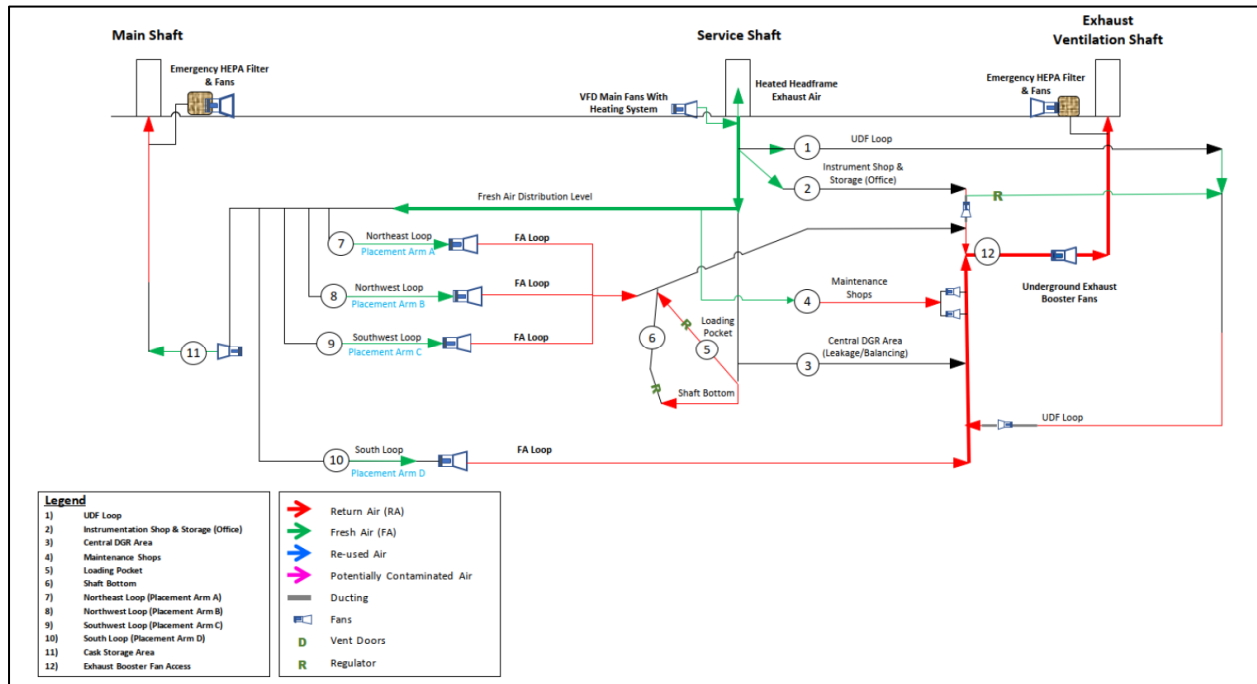


Figure 48: Ventilation Overview for the Crystalline Geosphere

5.8.2 Estimation of Air Flow Requirements

In assessing airflow requirements, the DGR will be subdivided into two areas: the Services Area and the repository arms in the placement area. These areas will be essentially ventilated independently. In both cases, airflow rates will be sufficient to allow a suitable working environment for personnel. In the case of the placement area, airflows will be based on the sum of that needed for repository development/excavation and for actual buffer box placement activities, since the two operations will be performed concurrently.

Unless otherwise specified, the minimum airflow velocity in all access tunnels and occupied placement rooms will be 0.5 m/s as a general mining best practices consideration for areas with no diesel equipment or other controlling factors. During buffer box placement, the minimum air velocity will be reduced to 0.25 m/s in the placement rooms. Use of battery powered emplacement vehicles and requirement of no personnel to be allowed in placement rooms during actual placement allow this lower air velocity.

The ventilation system will be capable of delivering air at a velocity of 3.5 m/s to prevent fire rollback. Fire rollback can cause hot combustion products (smoke and gas) to move along the roof of tunnels in the opposite direction to primary ventilation flow, potentially circulating combustion products into areas upstream from the fire source. Fire rollback can be a dangerous threat to workers and firefighters in an underground repository. By preventing fire rollback, the chances for safe worker evacuation and effective firefighting can be improved. In the remote event there is a fire in an access tunnel, airflow velocity of at least 3.5 m/s will prevent fire rollback.

The maximum allowable airflow velocity in any underground opening is 6 m/s. At airflow velocities above 6 m/s dust and other particles become entrained in the air which can cause uncomfortable

working conditions. High airflow velocities are also uncomfortable for workers and hinder communications.

During development of the placement rooms, the airflow needed at the working face area will be approximately 4 m³/s. Two 55 kW fans in series operation will deliver the air quantity required. During buffer box placement, the airflow quantities needed at the working face area were determined to be about 2 m³/s. As indicated below in Table 17, the airflow intake through the Service Shaft for the DGR will be 378 m³/s during operations phase. The summarized exhaust airflows do not account for exfiltration and losses through the service shaft headframe.

Table 17: Shaft Airflow Requirements

Air Way Type	Shaft	Airflow Requirements (m³/s)
Intake	Service Shaft	378
Exhaust	Exhaust Ventilation Shaft	311
	Main Shaft	40

5.8.3 Fan Systems

The surface fans at the Service Shaft will be designed to deliver fresh air to the shaft-plenum intersection where a small volume of air will travel up to the headframe and the balance of the airflow will go underground. From within the shaft, air will be drawn under the influence of the underground booster fans. Table 18 shows the data for the proposed fans including their calculated motor powers.

Fan system sizing will be influenced by repository depth and length of access tunnels/repository arms (i.e., distance from Service Shaft). At this time, the hypothetical crystalline rock geosphere layout has longer access tunnels; as result, it will require larger fan systems than the sedimentary. The ventilation systems of both the crystalline and sedimentary geospheres will change in future to reflect the actual underground conditions derived from the information received from the site investigation work.

A 10% allowance will be included in the fan motor requirements for events that may require additional power during operations. This can be due to friction factor changes due to mining systems or the movement of equipment in shafts and station areas. Further, all primary fans will be installed with a variable frequency drive, to have the flexibility of operating at different flow ranges depending on the required system conditions.

Table 18: Fans and Related Specifications**Crystalline Geosphere**

	Number of Installed Fans	Total Flow (m ³ /s)		Fan Total Pressure (Pa)		Power Consumption per Fan (kW)		Motor Size (hp)
		Nominal	Design	Nominal	Design	At Nominal Flow/Pressure	At Design Flow/Pressure	
Service Shaft Surface Fans	2	477	525	1245	1657	467	621	960
U/G Booster Fans	2	407	448	2202	2815	676	900	1350
Cask Storage Area Fans	2	42	46	1706	2214	55	73	120
Service Fans	2	36	40	120	146	3	4	7.5
UDF Loop	2	32	35	135	163	3	4	7.5
E-UDF Loop	2	12	13	104	126	1	1	5.5
North East Arm Return Fans	2	163	179	2099	2691	259	345	550
North West Arm Return Fans	2	142	156	1663	2163	181	241	380
South West Arm Return Fans	2	152	167	2007	2579	232	308	500
South Arm Return Fans	2	186	205	4506	5603	615	819	1350

Sedimentary Geosphere

	Number of Installed Fans	Total Flow (m ³ /s)		Fan Total Pressure (Pa)		Power Consumption per Fan (kW)		Motor Size (hp)
		Nominal	Design	Nominal	Design	At Nominal Flow/Pressure	At Design Flow/Pressure	
Service Shaft Surface Fans	2	418	460	945	1294	319	425	675
U/G Booster Fans	2	351	386	1767	2289	474	631	960
Cask Storage Area Fans	2	41	45	1377	1817	44	59	100
Service Fans	2	36	40	79	96	2	3	5.5
UDF Loop	2	32	35	118	142	3	4	7.5
North Arm Return Fans	2	152	167	1331	1761	158	210	340
West Arm Return Fans	2	164	180	2288	2919	283	376	600
South Arm Return Fans	2	137	151	2367	3014	244	325	500

Main Shaft: The Main Shaft will be supplied with fresh air from a single Fresh Air Raise (FAR) connected to the fresh air distribution level. Air will be introduced to this area through a fan at the Cask Storage area elevation. The flow will be distributed through the cask storage area using an auxiliary fan and duct system for even distribution. Air will be discharged to the Main Shaft under its own pressure and under normal operating conditions, this will be released directly to atmosphere at 9 m above grade.

Under relevant emergency scenarios, the air will instead be drafted through a dedicated HEPA filter and fan installed at surface. During normal operating conditions, the air velocity in the Main is 0.9 m/s. This means that should a release event occur at the DGR level, the air containing the release will be expected to reach surface in approximately 10 minutes. Considering currently available fan and damper designs, the HEPA system can be activated within that time. It should be noted that location and type of sensors to detect a release will be determined in future when the ventilation system is progressed to detailed design stage.

Service Shaft: The fans at the Service Shaft “push” air into the DGR with sufficient pressure to reach marginally negative pressures in the ventilation level. This air will be distributed across the repository through the fresh air distribution level, which is approximately 25 m above the DGR level. Fresh Air Raises (FARs) connect these levels. Flow will be distributed using booster fans installed at the DGR level.

Exhaust Ventilation Shaft: The Exhaust Ventilation Shaft will act as the primary exhaust route for the repository. Large underground booster fans discharge the majority of the air from the repository to atmosphere at 15 m above grade.

During an emergency scenario, air will be drafted through a dedicated set of HEPA filters, similar to the Main Shaft. The Exhaust Ventilation Shaft has a variable velocity contingent on the operating condition of the repository. At a maximum, the intended shaft velocity will be 7 m/s to avoid water droplet suspension with the exception of the fire rollback situation. During normal operating conditions, should a release event occur at the closest placement room to the shaft, it will take approximately 3 minutes for the air to reach surface. Considering currently available fan and damper designs, the HEPA system can be activated within that time. It should be noted that location and type of sensors to detect a release will be determined in future when the ventilation system is progressed to detailed design stage.

All exhaust ventilation system fans will be linked to provide reliable operation during an emergency. If one fan fails or electrical problems occur, the system of surface and underground fans will react to this change by either increasing or reducing airflows. The system would be automated for this purpose.

For the fan systems, the plenum will be one of the most important components as poorly designed plenums can reduce the pressure capacity of a primary fan by as much as 50%. The primary contributors to pressure losses in a plenum are shock losses and the airway cross-sectional area. The plenums will be thus sized to primarily reduce the air velocity head and hence, shock losses. The headframes will also be critical to fan performance, since a leaky headframe will lower the system pressure capacity.

5.8.4 Fresh Air Heating System

The underground ventilation system will be designed to ensure reasonable underground temperature conditions. This will allow personnel to work, at all times of year, in normal indoor work wear (coveralls, work boots, etc.) as in a surface factory setting. A direct-fired heating plant in the ventilation network will be used to maintain working temperatures during winter months. Support offices and ancillary facilities will also be kept at temperatures where work can be performed in every day indoor work wear, without the need for heavy clothing.

The size of a heating plant is a function of the required temperature change. Considering a change in temperature from -30°C (surface outside) to +10°C (shaft), and after accounting for anticipated system inefficiencies, an estimated 21 MW heating plant will be required. The heating plant will use burners placed directly into the airstream. Common in the northern hemisphere, such systems have proven reliable and extremely safe. A draw-through system, in which the fan will be located downstream of the line burner is proposed. Direct propane or natural gas fired heaters will consist of an intake section, burner section and air plenum. Integral blower burners will be mounted directly in the airstream. The control system for the heater and fan systems will include local controls and connection to the central control infrastructure.

During winter months, the shaft headframes will need to be heated to prevent freezing. As previously described, a push-pull arrangement will be established for the DGR's ventilation system using a force fan system on surface and exhaust booster fans located underground. All three shafts will have a headgear located on the top of the shafts. Therefore, to prevent freezing

problems during winter months, small portions of the heated air streams would be directed into the shaft infrastructure.

Airflow Rate in Exhaust Ventilation Shaft

When ventilation air flows up the Exhaust Ventilation Shaft it is subjected to the effect of “auto-decompression”. The air will decrease in temperature by 10 degrees Celsius for every 1000 metres of rise in elevation. If the air is not at 100% relative humidity when it enters the shaft it may reach 100% relative humidity as it cools. Once at 100% relative humidity, water may start condensing on the shaft walls if the walls are cooler than the air. As the air reaches 100% relative humidity, fog will be generated, the fog droplets will start combining to form water droplets. If the air speed is high enough the water will be carried out by the air stream up the shaft. If the air speed is low, then the water droplets will fall down the shaft.

Air speeds between critical range of 7 to 13 m/s can suspend water droplets in the shaft. Water blanketing may occur in this range of velocities. The resulting variations in shaft resistance will cause an oscillating load on main exhaust fans which may affect fan performance and/or lead to fan damage. Water blanketing can produce large intermittent cascades of water falling to the shaft bottom.

The Exhaust Ventilation Shaft inside diameter will be set at 7 m to maintain target airspeed below or close to 7 m/s. Selecting to stay below the critical range will be due to variable operating airflow rates over life of the DGR. Low airflow rates will also reduce resistance to airflow and thus leads to lower operating costs for the long life of the DGR.

5.8.5 Exhaust Air Filtration

High-efficiency particulate air (HEPA) filtration systems will be established (as shown in Figure 29) where underground air exhausts to surface at the Exhaust Ventilation Shaft and Main Shaft locations. These systems will be activated in the remote events of radioactivity being detected in the underground ventilation air at above-background concentration levels and/or an underground fire. They will be installed on surface in the exhaust ducting systems. For the Exhaust Ventilation Shaft, the HEPA filters will be bypassed during normal operations. In the remote event of underground radioactive release or a fire, a damper would be activated by triggering of an underground sensor resulting in redirection of the contaminated ventilation air in the exhaust circuits with HEPA filters. The HEPA filters and exhaust fans will be enclosed in a structure(s) for protection from the elements. The system will be routinely tested. A similar but smaller HEPA filter system will be installed at the Main Shaft.

HEPA filters will also be installed on auxiliary ventilation ducts for the placement rooms and will be available for use during UFC placement activities. A portable HEPA filter will be provided on the exhaust duct from active placement rooms and each duct will be equipped with a radiation monitor and bypass damper. In the remote event that radioactive contaminants are detected, the damper will be activated, and the air exhaust will be routed through the HEPA filters. At same time an alarm will be sounded for the evacuation of underground workers to a refuge station. A future risk assessment will be performed to determine if this portable HEPA filter system is required.

6. USED FUEL CONTAINER HANDLING AND PLACEMENT

The UFCs will be assembled into buffer boxes inside the Used Fuel Packaging Plant (UFPP) (see Figure 10). Fully assembled buffer boxes will be staged in this area while awaiting transfer to the Main Shaft. After final inspection, each buffer box will be placed loaded into a shielded transfer cask and then loaded onto a trolley. Using a tow vehicle, the trolley with transfer cask will be moved to the Main Shaft Hoist and then secured within the cage. Upon arrival at the repository level, the trolley with transfer cask is removed from the cage by another tow vehicle and then taken to the entrance of a placement room.

The following sections and associated story boards describes conceptual processes and equipment to be used in the handing and placement buffer boxes in the underground repository as well as associated room backfilling and room sealing activities. The handling and placement strategies are under development. The placement sequence described below will be optimized in the future after the surface-based mock-up tests are completed.

6.1 UFC PLACEMENT IN REPOSITORY

The buffer box placement process is outlined below. It should be noted that all activities in the placement rooms will be remotely controlled once the first buffer box has been received at the room entrance.

- The transfer cask (with buffer box) will be received from the UFPP via the Main Shaft cage on a trolley;
- Once underground, the transfer cask will be transported to a shielding canopy located at the entrance to a placement room. An ejection ram will allow the buffer box to be pushed out of the transfer cask;
- Floor plates (with integrated ventilation ducts) will then have been laid on top of the compacted GFM floor (reference floor smoothing treatment) up to the current placement location;
- Through the access window in the shielding canopy, the buffer box will be transferred to the placement vehicle waiting inside the shielding canopy;
- The placement vehicle will travel the length of the placement room to the final placement location;
- The placement vehicle will deposit the HCB floor tablet followed by buffer box. The Buffer box center-to-center spacing would be approximately 1.3 m and 1.7 m for the Crystalline and Sedimentary design cases, respectively. Vertically, the buffer boxes are stacked 2 high in a staggered pattern;
- After the placement of two buffer boxes, small HCB bricks for filling larger buffer box forklift or floor holes followed by an HCB floor tablet and two HCB spacer blocks would be placed in a similar fashion to the buffer box placement;
- The placement vehicle will exit the placement room through the shielding canopy;
- The GFM placement system will enter the placement room through the rear door of the shielding canopy and perform the placement operation by augering granular bentonite GFM in the annular spaces around the buffer boxes. It will then exit the placement room;
- The placement vehicle with the magnetic floor plate removal system will enter the placement room through the rear door of the shielding canopy, remove a floor plate segment and then exit.

Graphical storyboards of the key steps in the conceptual transfer and placement of the UFCs/buffer boxes are provided as Figure 52, Figure 53, Figure 54, and Figure 55. The first of these illustrations provides a summary of the required placement equipment.

Three placement operations are expected to be performed in parallel to achieve the required annual 2,500 buffer box through put.

6.1.1 Placement Equipment

Various pieces of equipment will be developed specifically for this facility due to the unique nature of the work. The placement equipment to be used are illustrated in the legend located at the beginning of Figure 52.

Shielding Canopy: The buffer box placement concept relies on shielded operations for all activities that occur after the buffer box is received at the placement room entrance (See Figure 49). This mobile canopy will permit shielded activities to take place inside, while also allowing use of the panel access tunnel by passing vehicles and personnel. Where required, the small annular space around the canopy perimeter can be covered by manually placed lead shielding packs to ensure no radioactive shine escapes around the edges.

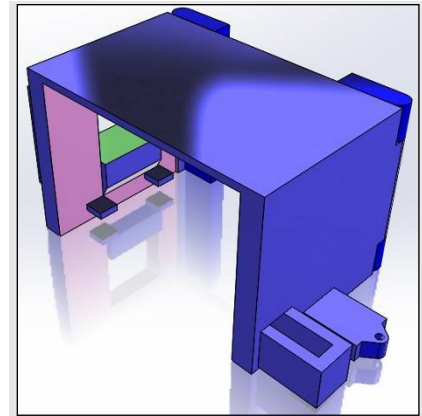


Figure 49: Shielding Canopy

The canopy design features include shielded hinged access doors for vehicle access and for buffer box insertion. A shielded access window is also included to allow buffer boxes and HCB spacer blocks to be passed through.

Floor Plates with Ventilation Ducts: The use of temporary metal plates with integrated ventilation ducts will facilitate equipment access to the work face (See Figure 50). Fresh air will be delivered into the placement room via room cross-section. The air will then be exhausted (“sucked”) from the room via the ventilation duct which will remove heat and dust from the room.

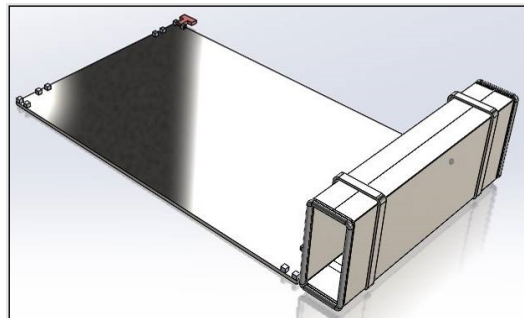


Figure 50: Floor Plate with Built-in Ventilation Duct

The floor plates would be installed before start of buffer box and floor tablet placement activities. As placement activities progress towards the room entrance, segments of floor plate will be removed. A magnetic attachment on the placement vehicle would be used to pick up the plate segments and bring them out of the placement room.

Buffer Box Placement Vehicle: This remotely controlled underground vehicle will be based on a highly customized commercial electric forklift with various enhancements including built-in remote operation sensing, lighting, and camera equipment as well as a customized lifting attachment to accommodate the bentonite floor tablets, buffer boxes and HCB spacer blocks. It

will also have an attachment for placing the floor plates. At least five placement vehicles are expected to be needed, assuming up to three active placement rooms are working in parallel and two vehicles are held as spares for maintenance rotations.

Bentonite Gap Fill Material (GFM) Placement System: For every two buffer boxes and two HCB spacer blocks that are placed, all annular spaces around the boxes will be filled with GFM. Using a piece of equipment similar to the placement vehicle, the bentonite placement system will rely on augured insertion of the granular bentonite using nozzles that can access all annular spaces around the buffer boxes.

6.2 BACKFILLING AND SEALING OF PLACEMENT ROOMS

Once the placement room has been filled with UFC / buffer boxes, a stack of HCB spacer blocks will be assembled after the last buffer box. The length of placement room between the last placed buffer box and the start of the room seal will be about 5 m. Two stacked rows of four 1 m thick HCB blocks will be required for both crystalline and sedimentary geospheres. The annular space around the blocks will be filled with GFM similar to the process used during buffer box placement.

The HCB spacer block placement process will require several pieces of equipment:

- Placement vehicle for spacer blocks;
- Shielding canopy and trolley;
- Bentonite GFM placement system;
- Floor plate handling system;
- HCB spacer block trolley; and
- Tow vehicle.

Once the room has been successfully backfilled, a room seal would be installed. The arrangement of the generic room seal is illustrated in Figure 51. The annular space around the blocks will be filled with GFM in parallel with the block placement process. The placement room seals in the crystalline and sedimentary geospheres will be similar.

Equipment required for the room seal construction process will generally be consistent with that needed for placing the HCB spacer blocks except vehicle for the spacer blocks and the shielding canopy, which will not be required. Once complete, the placed spacer blocks are expected to provide adequate shielding from the buffer boxes to allow the room seal and concrete bulkhead construction operations to be completed without shielding.

Once the room seal is complete the concrete bulkhead can be installed. The completed concrete bulkhead will be recessed approximately 10 m from the entry to the placement room.

A simplified graphical storyboard of the key steps involved in the backfilling and room seal construction process is depicted in Figure 56. Immediately preceding the storyboard, a summary of the required equipment is provided in the legend.

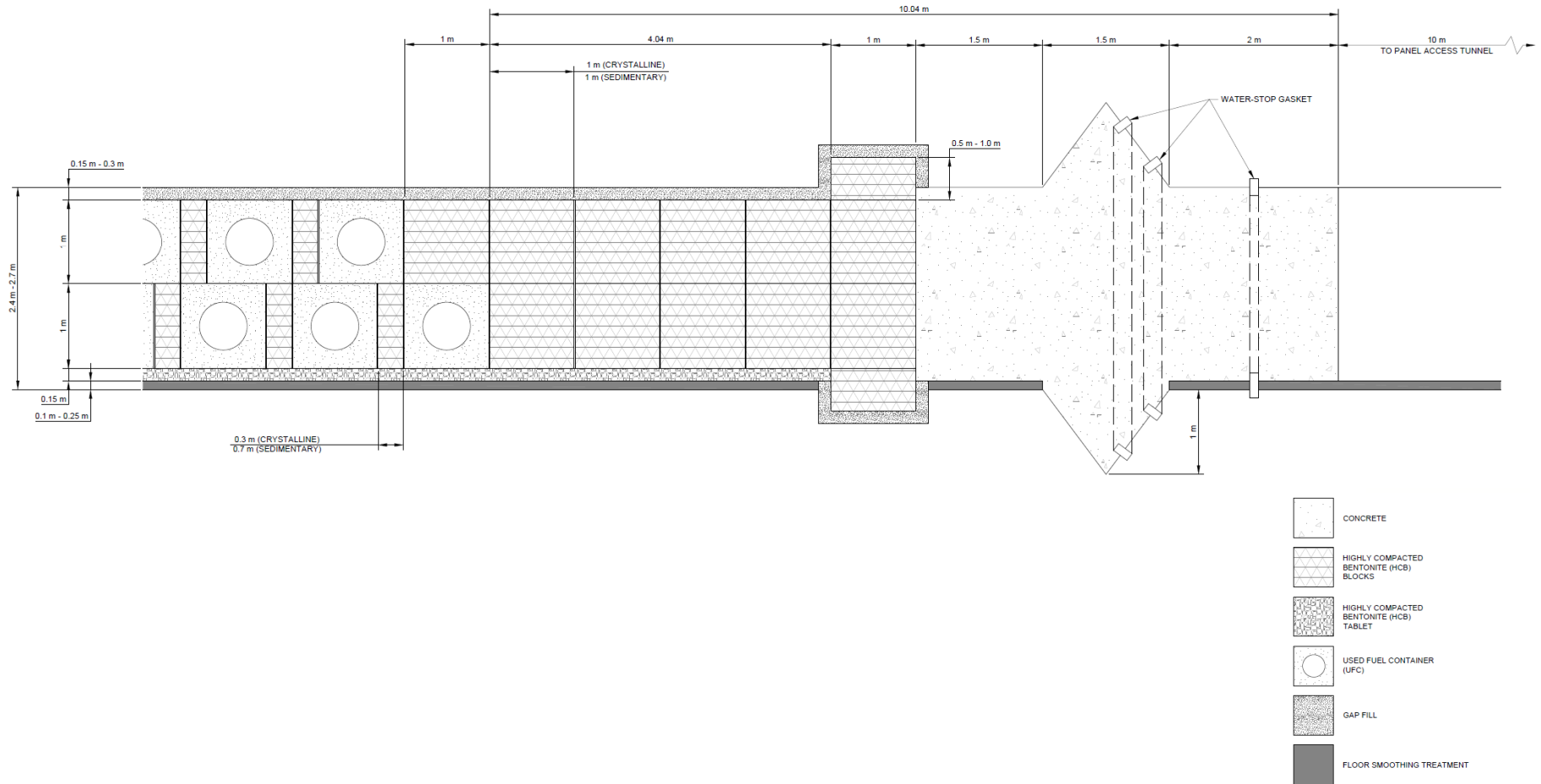


Figure 51: Generic Placement Room Seal

Legend for Generic Container Placement Equipment

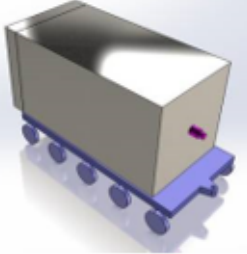
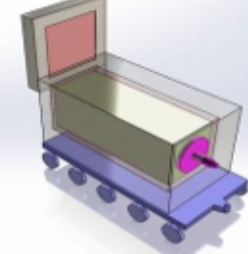
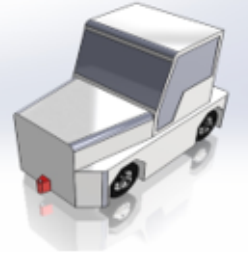
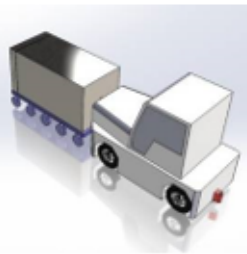
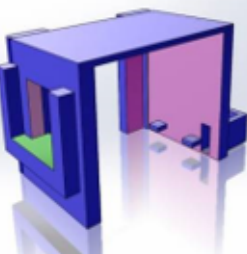
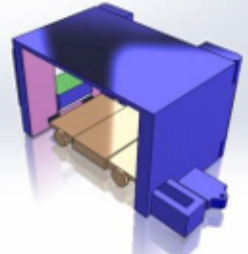
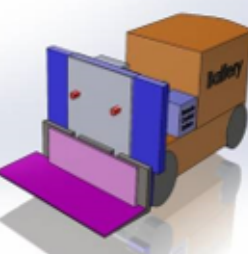
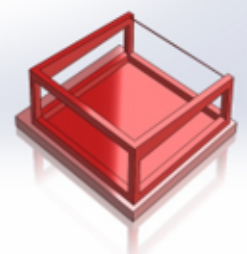
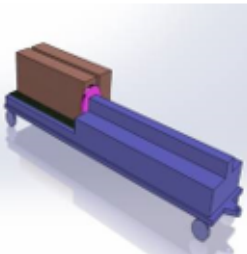

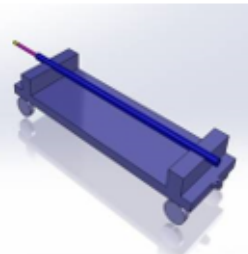
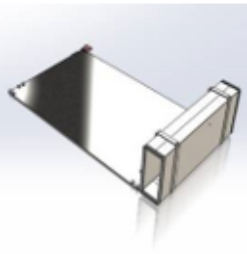
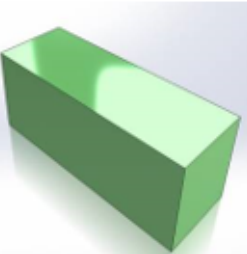
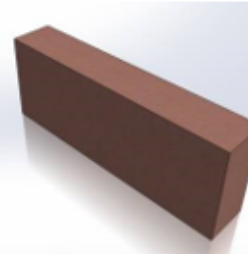

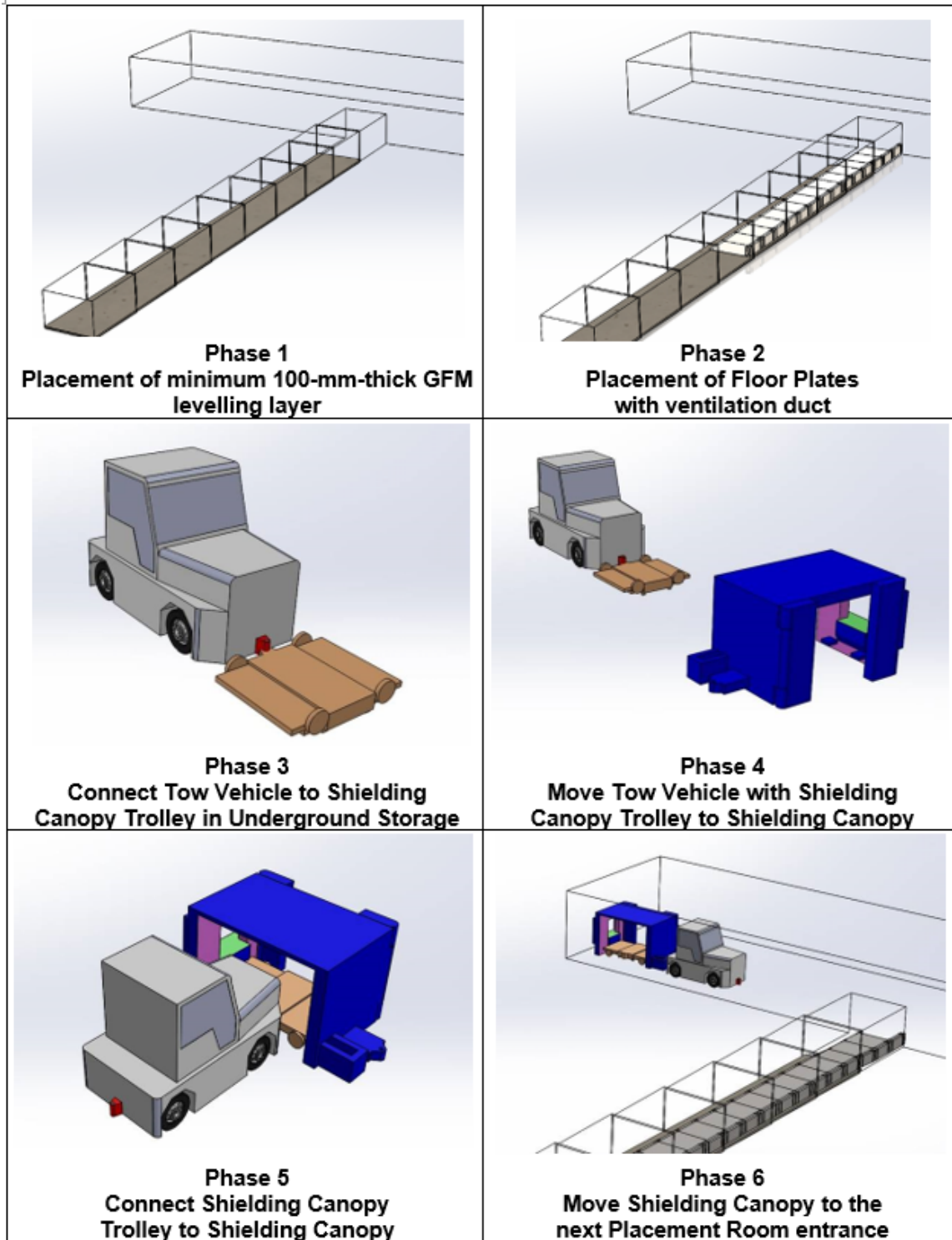
 <p>UFC Transfer Cask & Trolley</p>	 <p>UFC Transfer Cask Door Open with UFC</p>	 <p>Tow Vehicle</p>	 <p>Tow Vehicle with UFC Transfer Cask</p>
 <p>Shielding Canopy</p>	 <p>Shielding Canopy with Trolley</p>	 <p>Placement Machine</p>	 <p>Floor Plate Handling System</p>
 <p>Trolley for Bentonite Blocks</p>	 <p>Bentonite Gap Fill Placement System</p>	 <p>Hydraulic Cylinder Cart</p>	 <p>25-mm-thick Floor Plate with Ventilation Duct</p>
 <p>Buffer Box</p>	 <p>HCB Spacer Block</p>	 <p>UFC</p>	

Figure 52: Generic Preparation of Placement Room & Shielding Canopy - Sequence of Operations



Generic Preparation of Placement Room & Shielding Canopy - Sequence of Operations (continued)

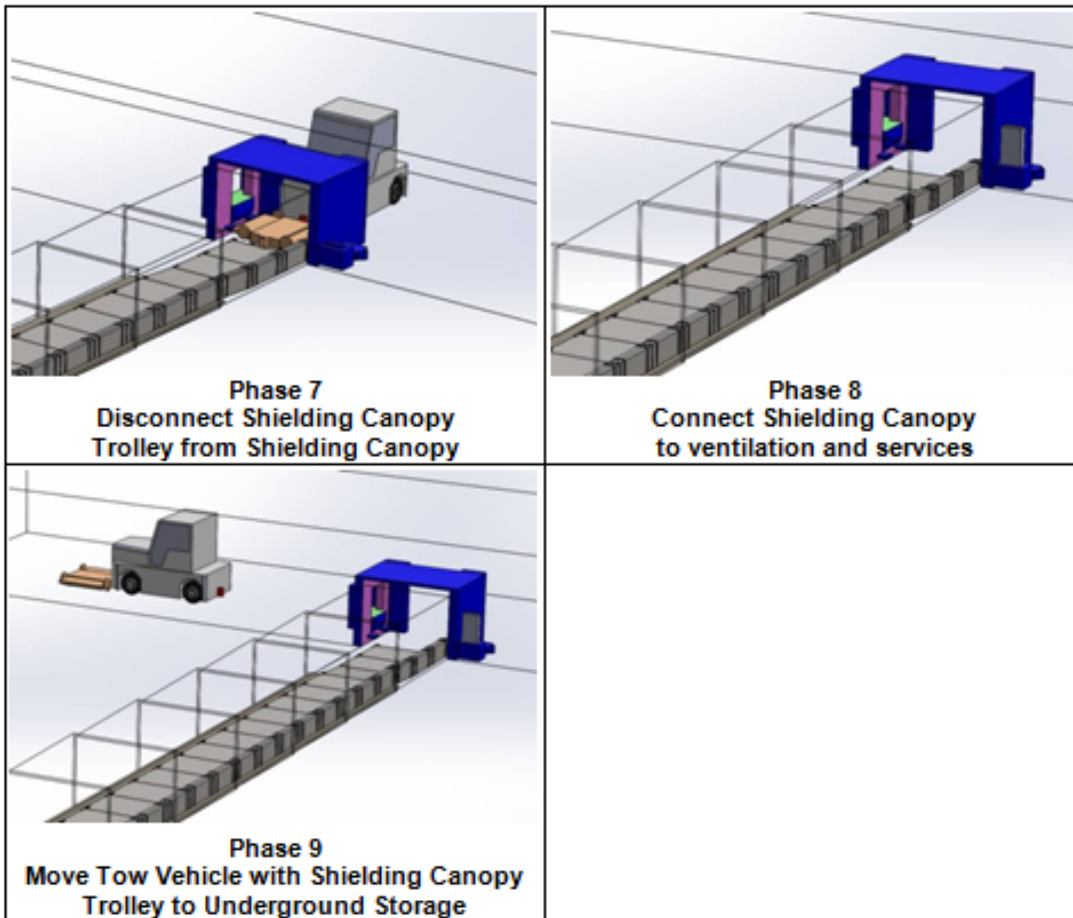
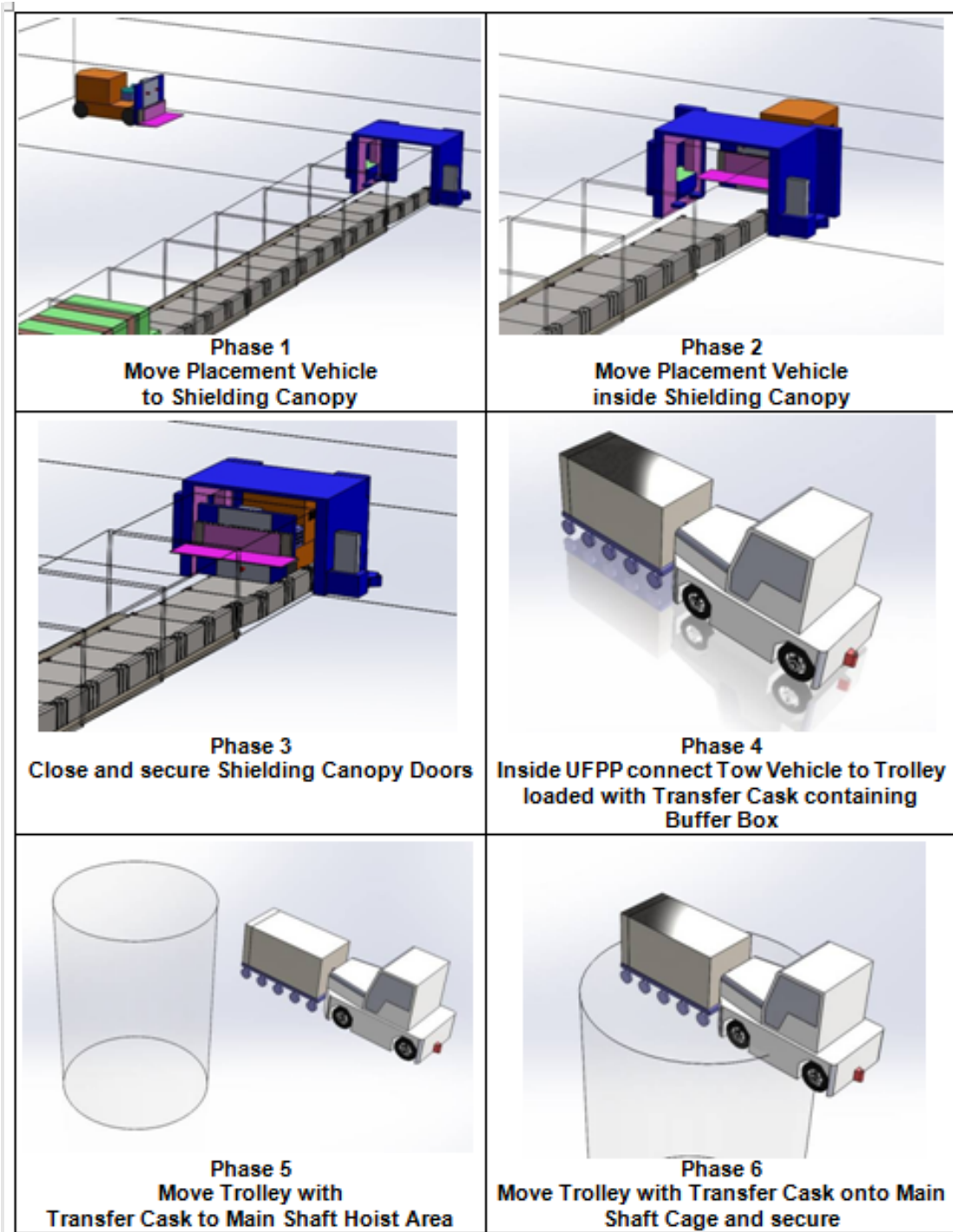
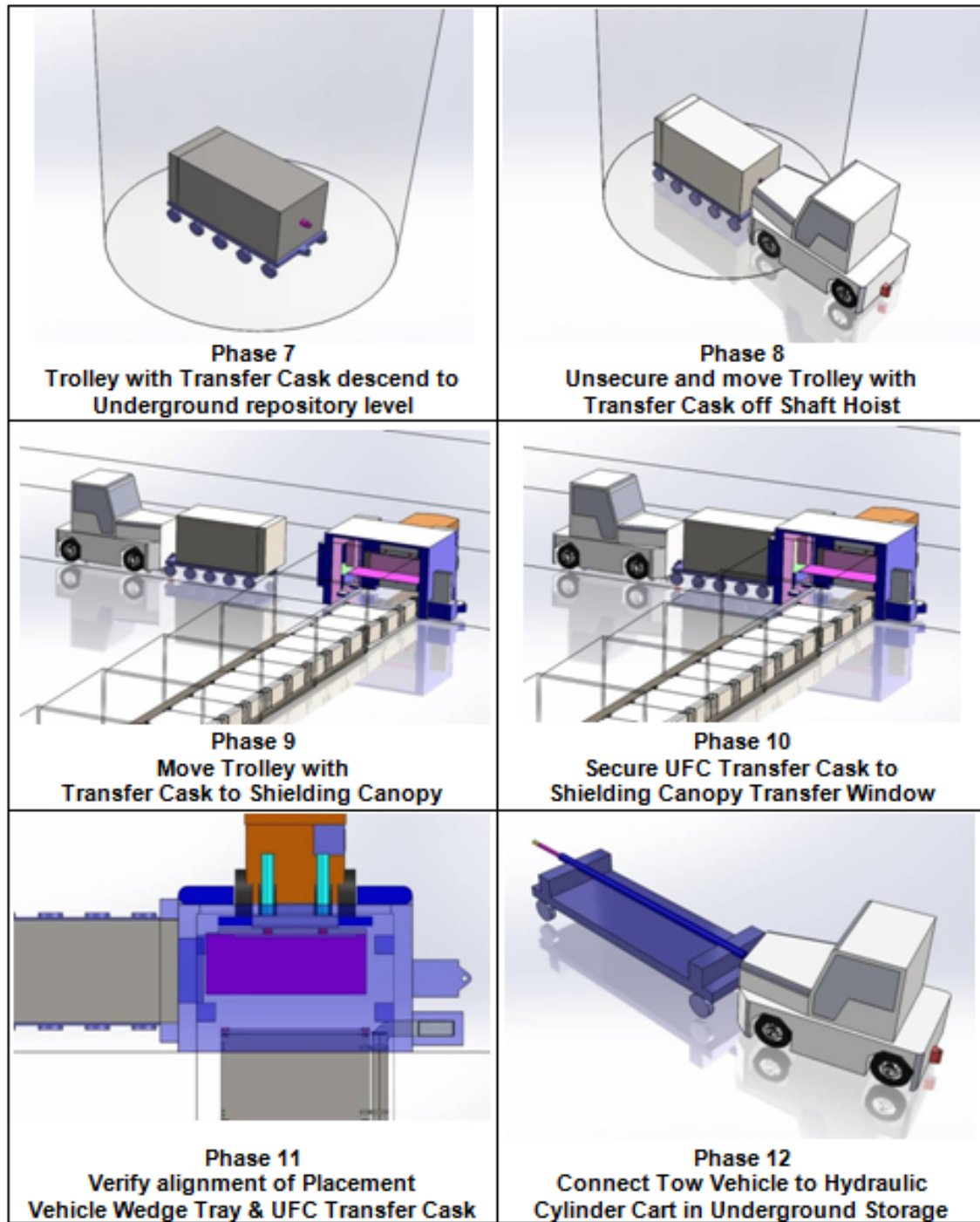
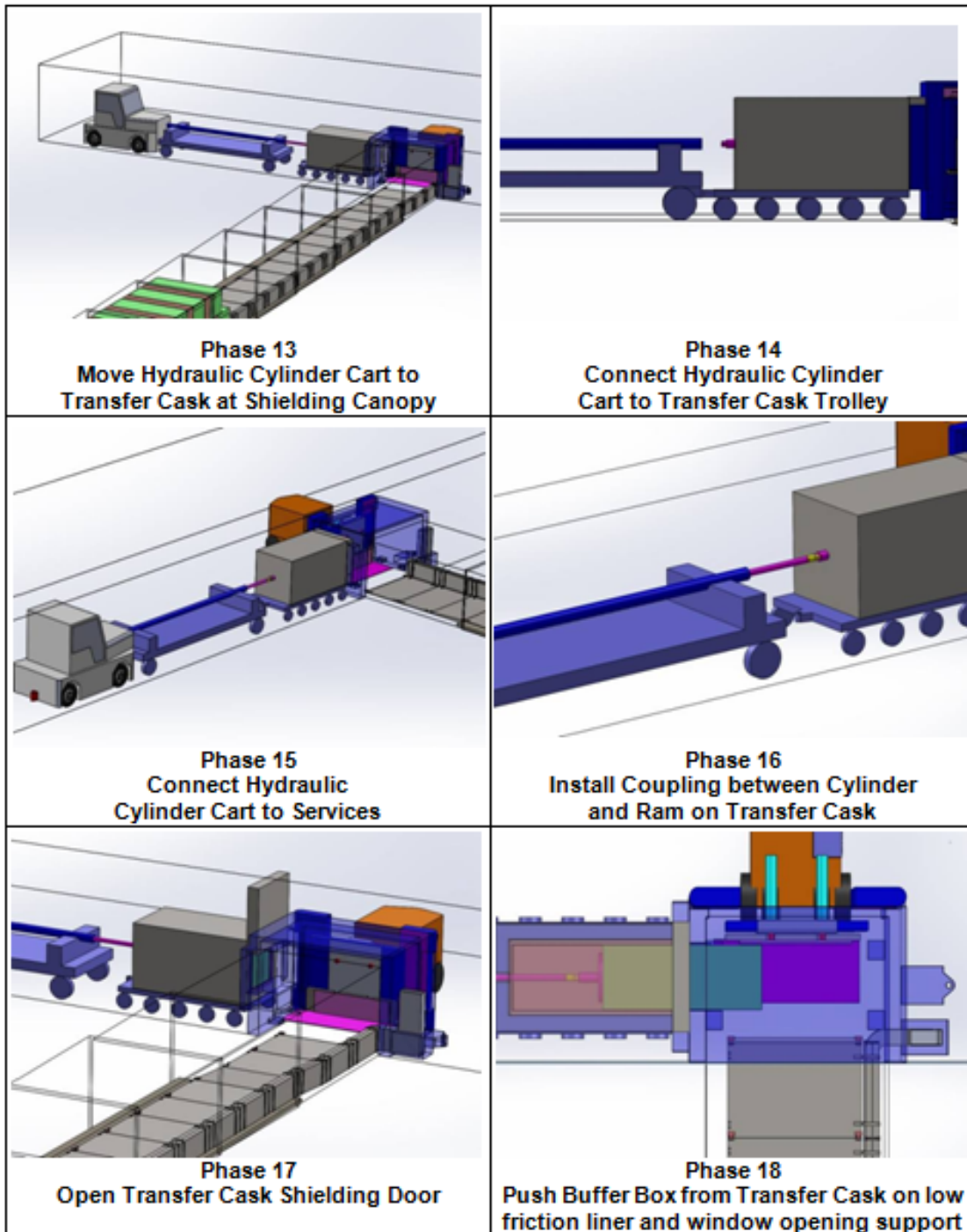


Figure 53: Generic Container / Buffer Box Placement - Sequence of Operations

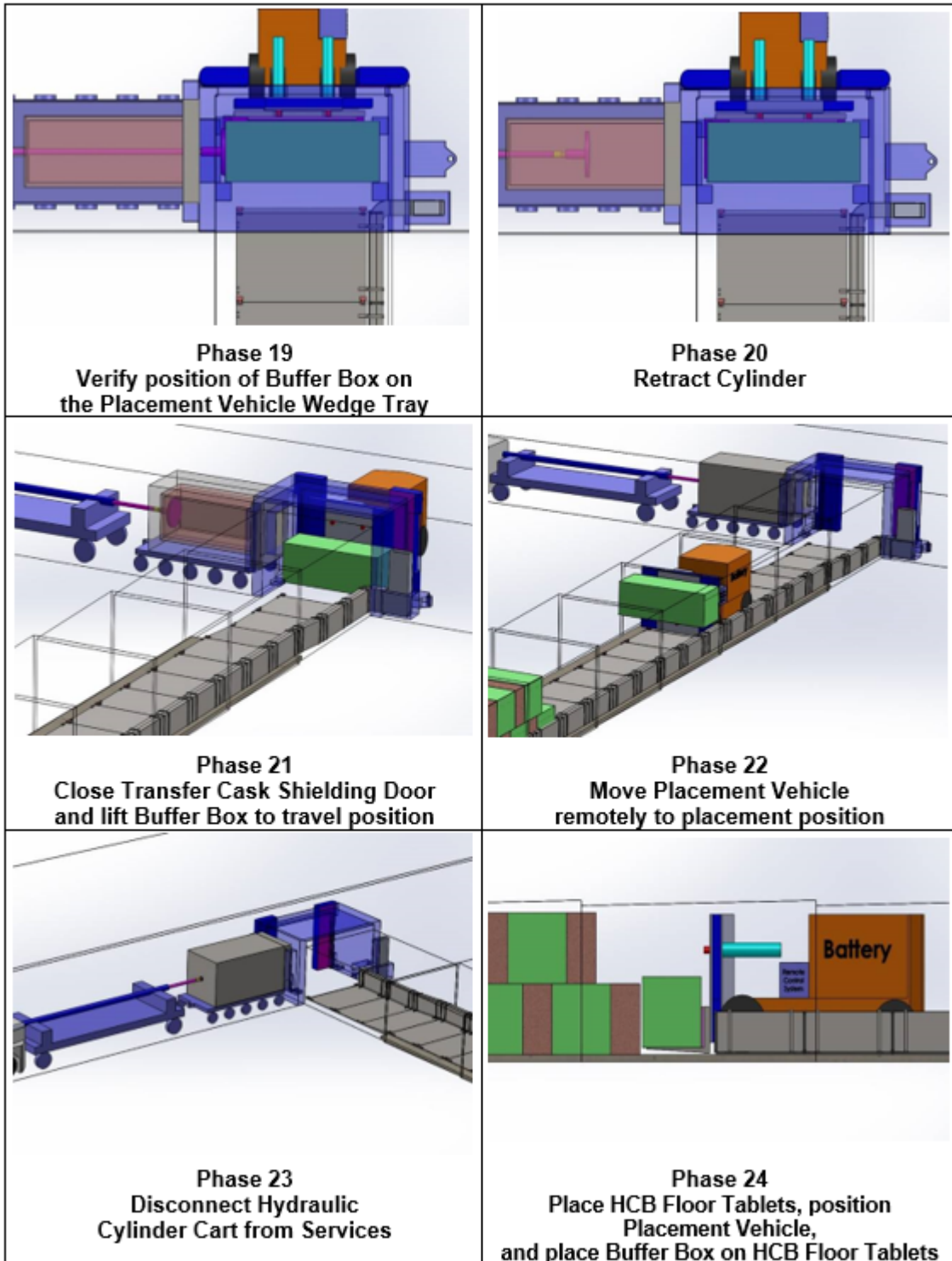


**Generic Container / Buffer Box Placement - Sequence of Operations
(continued)**

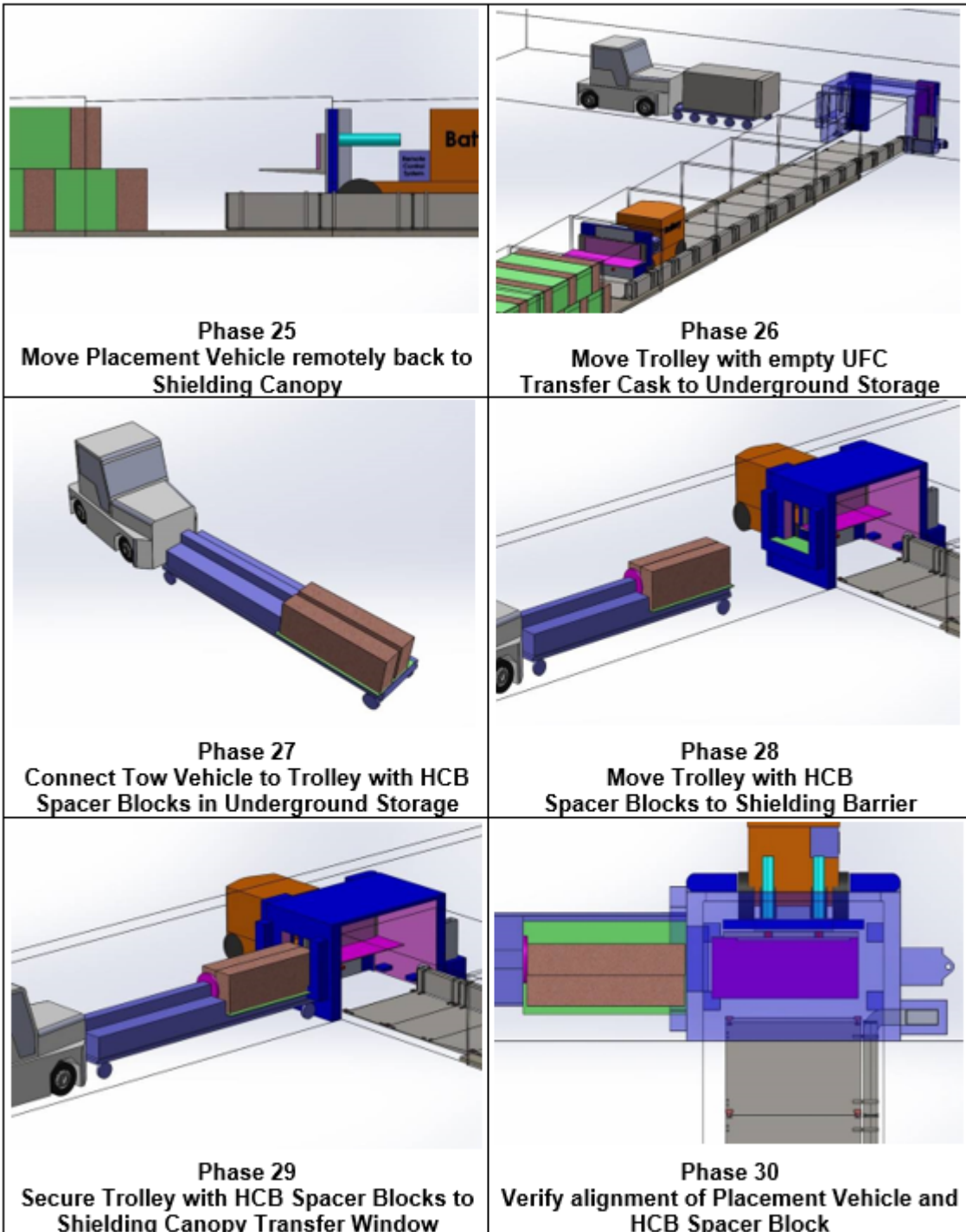
**Generic Container / Buffer Box Placement - Sequence of Operations
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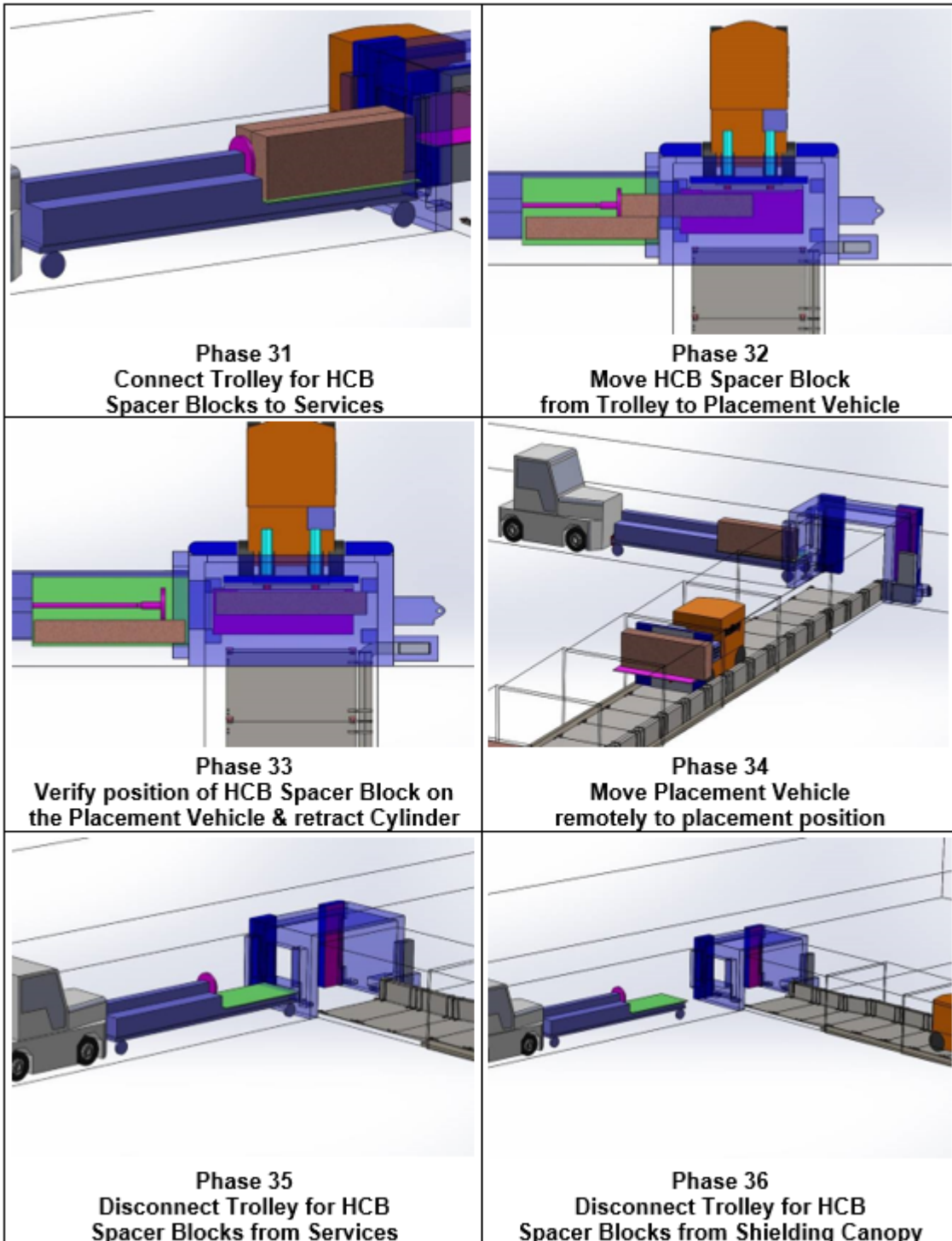
Generic Container / Buffer Box Placement - Sequence of Operations (continued)



**Generic Container / Buffer Box Placement - Sequence of Operations
(continued)**



**Generic Container / Buffer Box Placement - Sequence of Operations
(continued)**



**Generic Container / Buffer Box Placement - Sequence of Operations
(continued)**

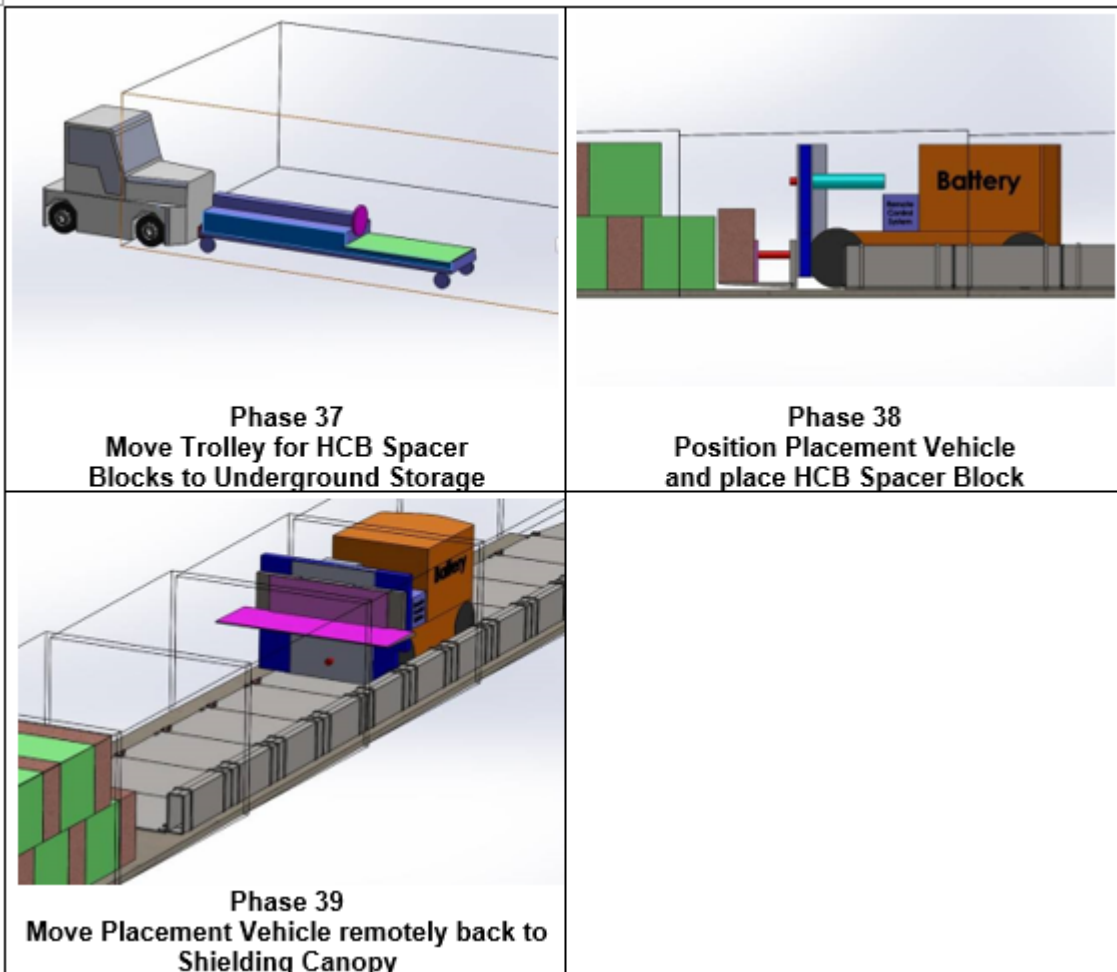


Figure 54: Generic Bentonite GFM Placement - Sequence of Operations

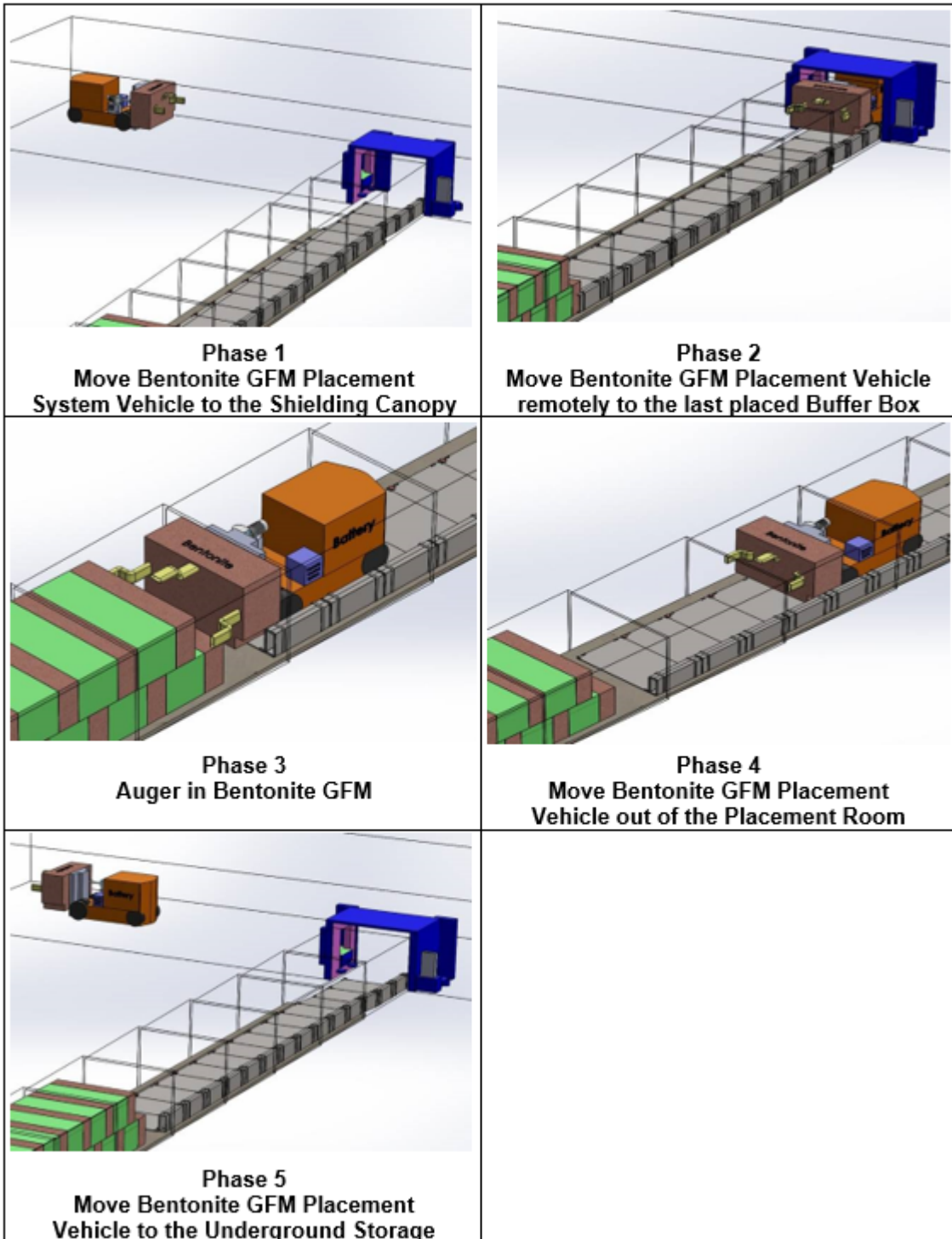
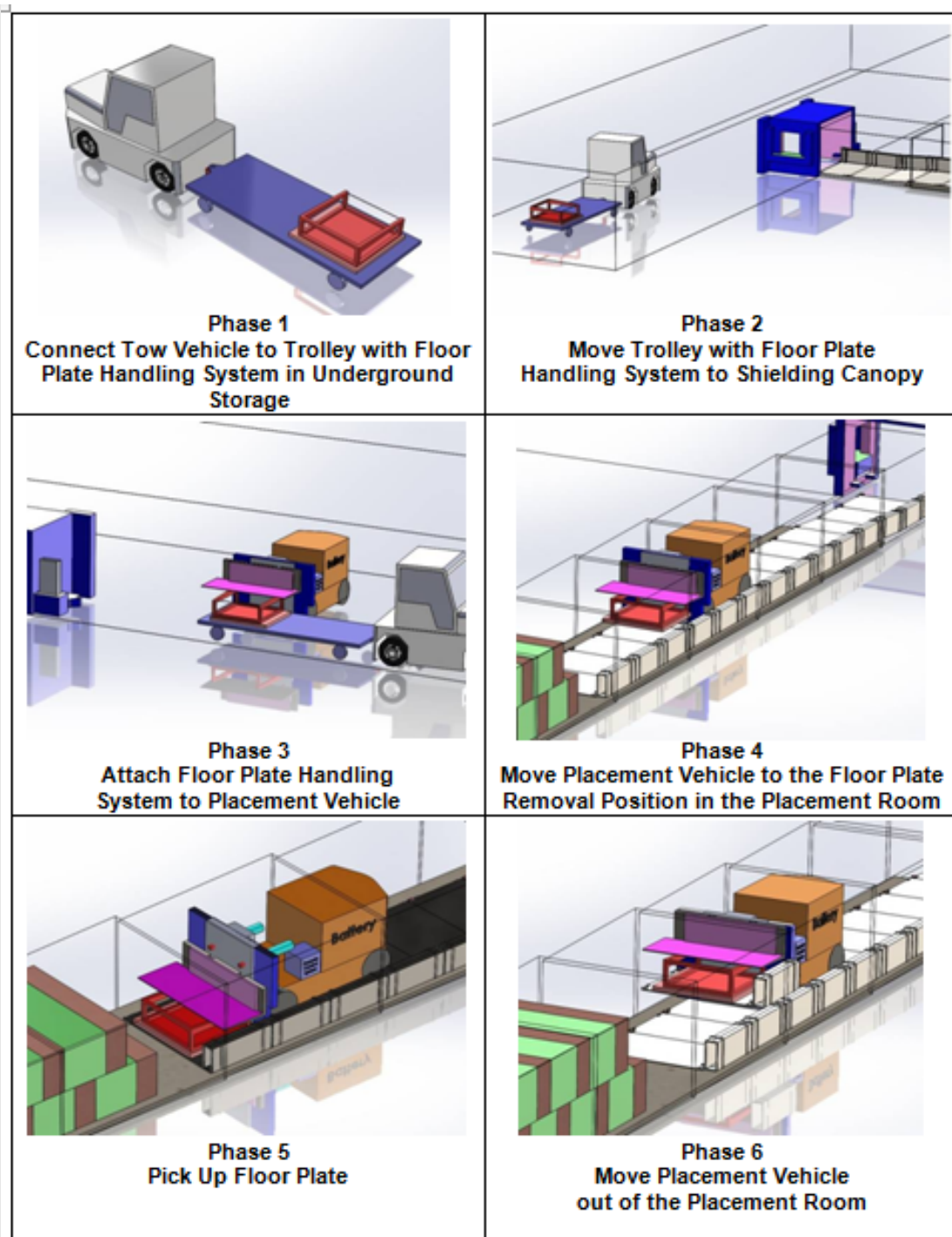
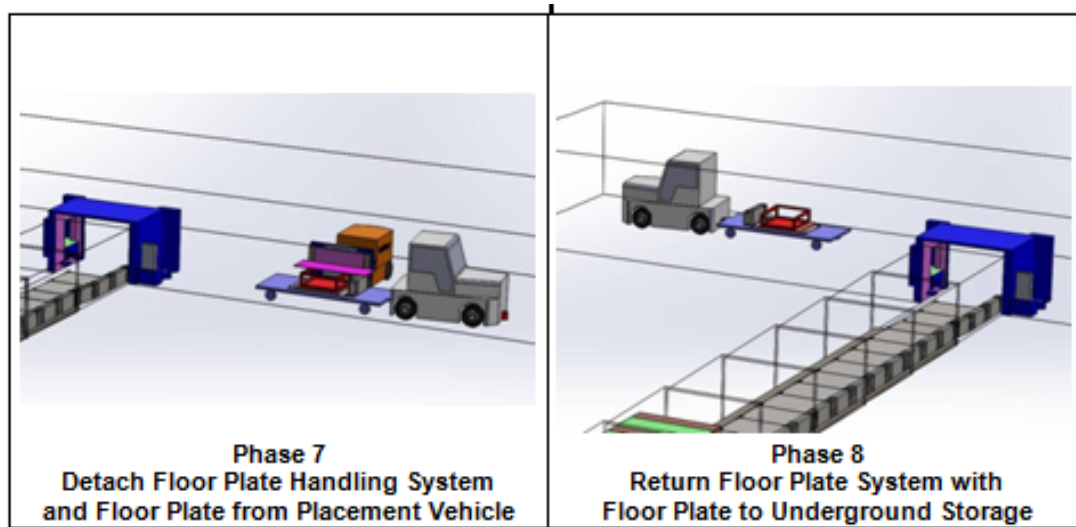


Figure 55: Generic Floor Plate / Ventilation Duct Removal - Sequence of Operations



Generic Floor Plate / Ventilation Duct Removal Operation (continued)



Legend for Placement Room Generic Sealing Equipment

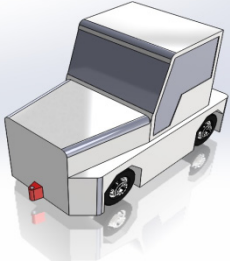
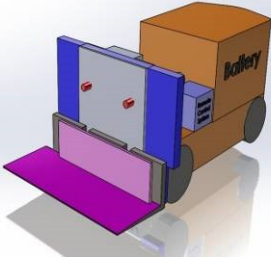
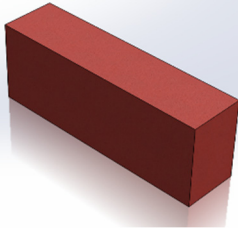

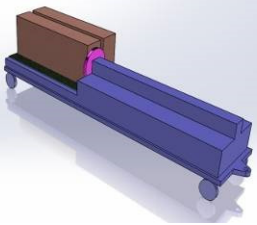
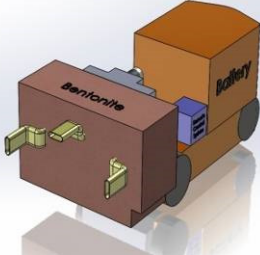
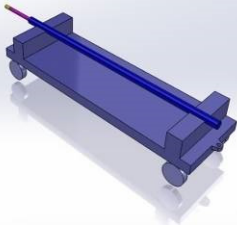
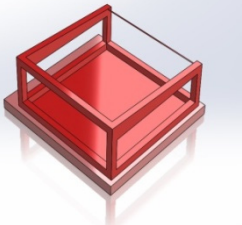
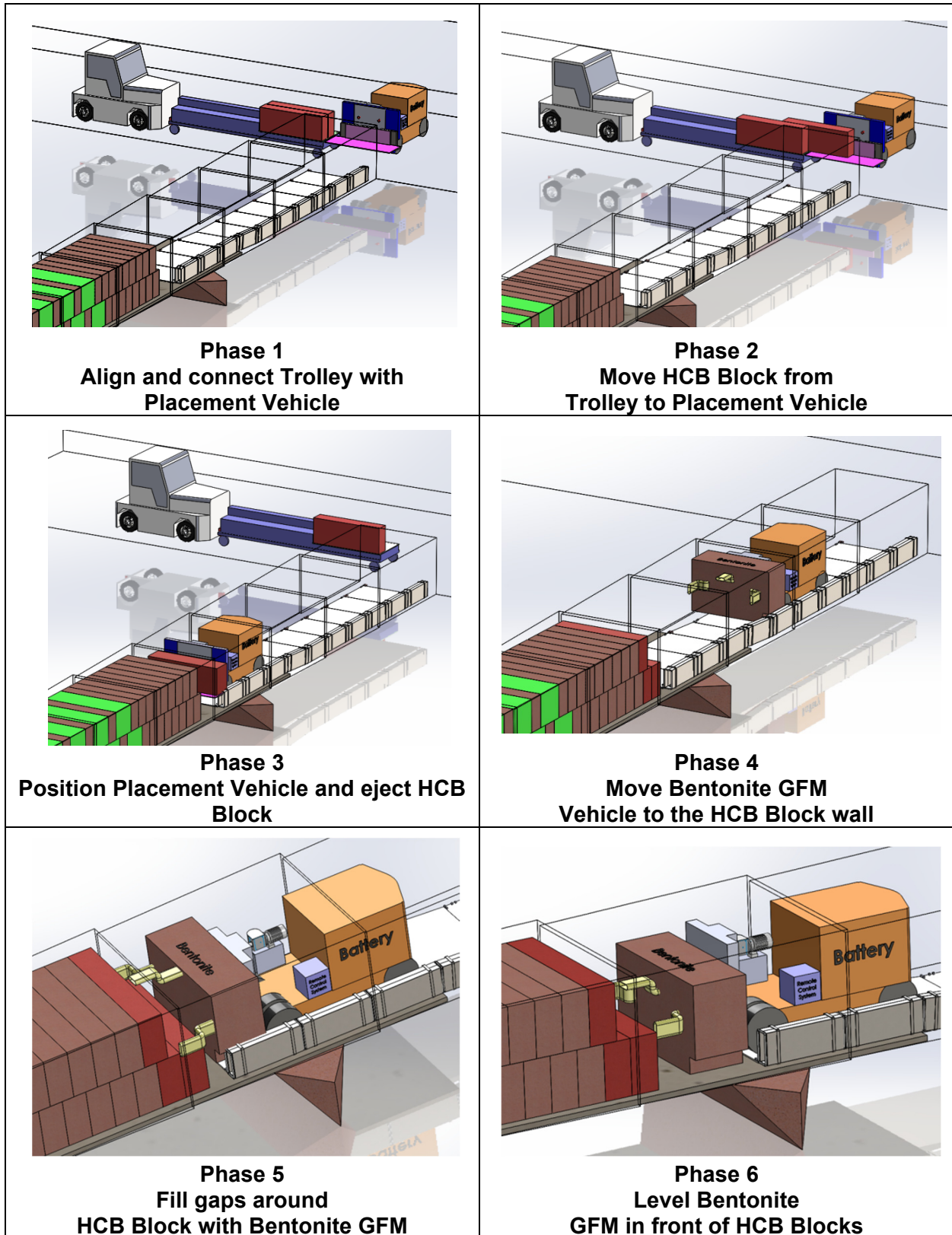
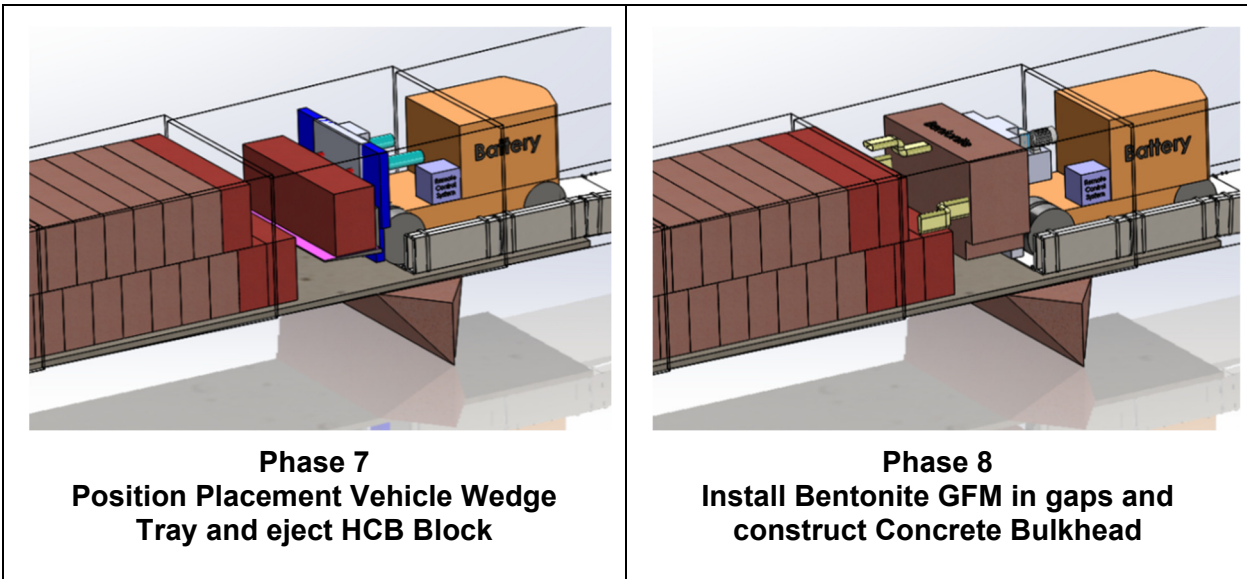
 <p>Tow Vehicle</p>	 <p>Placement Vehicle</p>	 <p>Spacer Block</p>	 <p>HCB Bricks and Tablets</p>
 <p>Trolley for HCB Blocks and Bricks</p>	 <p>Bentonite GFM Placement System</p>	 <p>Hydraulic Cylinder Cart</p>	 <p>Floor Plate Handling System</p>

Figure 56: Generic Sealing of Placement Room – Sequence of Operations



Sealing of Placement Room – Generic Sequence of Operations (continued)



7. CONTAINER RETRIEVAL

The following section describes the approach for a buffer box/container retrieval system to safely extract a UFC (inside a buffer box) from its location in the repository for subsequent transfer to the DGR surface facilities. There are two major stages in the retrieval operation: providing access to the target buffer box with its UFC and retrieving the buffer box.

7.1 GAINING ACCESS TO TARGET UFC

Activities related to providing access to the target buffer box (with its UFC) will be significantly impacted by the location of the buffer box within a particular placement room as well as the length of time that has passed after its placement.

The immediate retrieval of a buffer box (and UFC) when the placement room is still open will not have to contend with the backfill used to seal the placement room. Secondly, and depending upon the extent that the placement room's development has been completed, the room's concrete bulkhead may or may not be in place.

The primary backfill materials in the placement rooms will be in the form of HCB floor tablets, spacer blocks and GFM. Of particular importance to the buffer box retrieval process are the characteristics of these materials, some of which may have been in place for an extended period of time. Over time, the placed backfill materials may evolve from an unsaturated to a saturated condition. Alternatively, the heat produced from the UFCs may also cause some of this fill to become dry.

The amount of water saturation that the surrounding bentonite will experience is also important for buffer box retrieval. Bentonite swells with moisture becoming a significant barrier to water movement but, more importantly, the swelling will introduce a gripping pressure on the buffer box. The net effect of this pressure is that a simple mechanical means of pulling the buffer box from a placement room cannot be performed by extraction equipment until the gripping pressure has been relieved.

The immediate impediments to buffer box retrieval (removal of the concrete bulkhead, the room seal bentonite materials, etc.) are discussed below. As noted, in order to minimize mechanical disturbance to the placed UFCs from transmitted lateral forces, the reuse of drill & blast techniques previously employed for the development of the repository was not considered to be appropriate (material hauling vehicles, the LHDs and haul trucks, may still be used).

7.1.1 Concrete Bulkhead Removal

To remove the concrete bulkhead without mechanically disturbing any placed UFCs, a non-explosive expansion agent will be used. Under such an approach, boreholes would be drilled into the concrete bulkhead and loaded with an expansion agent. Commonly available as powder-based materials that are mixed with water for activation, such agents can generate a high expansive stress without the ground vibration that is associated with drill & blast methods. The agent expands as it cures over a period of hours or days generating sufficient pressure to break the concrete (the bulkhead may require some cutting to allow room for expansion). The resulting concrete fragments are then removed through traditional mining material removal techniques.

7.1.2 Room Seal Removal

The room seal is comprised of a number of HCB blocks and bricks placed in a stacking arrangement to fill the cross section of the placement room. Its removal process must result in a flat, structurally stable travel surface over this area for retrieval operations to be performed. The floor notch itself would be excavated and refilled with gravel or a suitable structure for vehicle travel. The removal work will need to either take into account protection for any manual processes or it must be accomplished in a completely remote fashion. As the room seal is removed, there will be progressively less radiation protection from the UFCs (inside buffer boxes) behind it.

7.1.3 Removal of HCB Spacer Blocks and Gap Fill Material

The backfill in the placement room will be composed of a series of HCB spacer blocks as well as gap fill material. To effectively carry out the removal of this material without mechanically disturbing the placed UFCs, a hydrodynamic method will be employed. The basic premise is to wash away the backfill materials with a saline water solution. While potentially time consuming, the reasons for proposing a hydrodynamic technological approach are:

- The approach has been demonstrated in other applications as an effective means to eliminate gripping pressures prior to attempting container retrieval;
- Simultaneous chemical and mechanical action on the buffer erodes the compacted bentonite in any state (ranging from dry and hard to fully saturated);
- The method can be applied in a continuous process with little risk of damage to the UFC; and
- No bulky load bearing or positioning structural parts are needed (compared with equipment that uses some type of mechanical freeing technology).

The method essentially consists of two stages: slurring of the backfill materials and dewatering of the generated slurry (which will contain a large volume of water).

Technology is currently available to deal with slurries (a common requirement in many mining applications) and a multi-stage separation process may be employed. The key component technology, however, will be based on the mechanical dehydration of sludge using a common decanter centrifuge process. Figure 57 shows a typical decanter centrifuge for bentonite slurries.

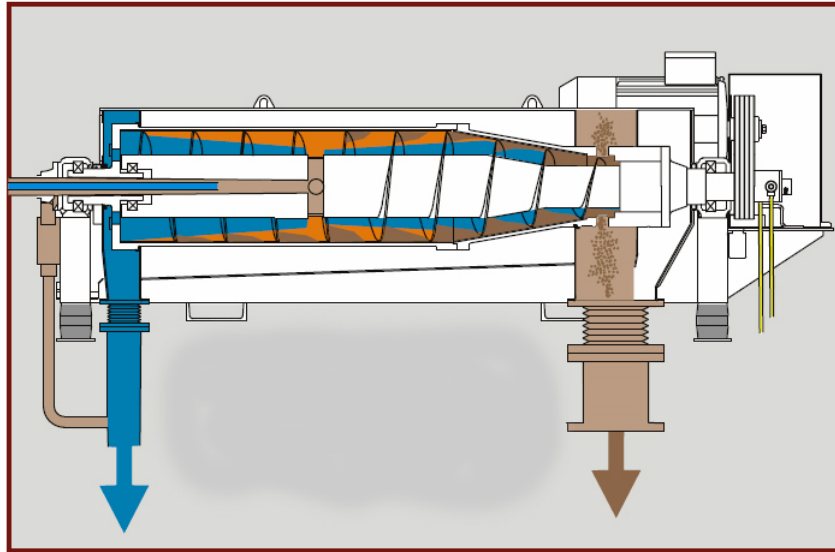


Figure 57: Typical Bentonite Decanting Equipment

The bentonite decanting system could be located outside the placement room in the access tunnel with hoses attached to the retrieval vehicle. Alternatively, the decanting system could be mounted on a unique piece of equipment similar to the placement vehicle. This would allow for a remotely controlled closed-loop bentonite collection and decanting system, integrated into an existing vehicle's power and control infrastructure.

While highly unlikely, it is possible that the slurry removed from the placement room may be classified as very low-level waste (VLLW) or possibly low-level waste (LLW) and would have to be managed accordingly.

7.2 UFC EXTRACTION AND RETRIEVAL

Once the backfill has been removed, the actual UFC retrieval process can be started. The envisaged process has primarily been influenced by the need to ensure a safe retrieval with continuous radiation shielding to allow unrestricted movement of personnel outside of the placement room as well as the effective re-use of placement equipment. The retrieval methodology has been based, to the extent possible, on the reversal of placement operations.

Some of the placement equipment can be re-used for retrieval like the buffer box transfer cask, the shielding canopy and the associated trolleys. The shielding canopy and trolley, for example, would be outfitted with an ejection ram to allow the UFC to be pushed off the retrieval vehicle into the transfer cask. New equipment required for the retrieval operations will include a lift for the UFC, hydraulic cylinder carts and tow vehicles. Retrieval vehicles would be equipped with retractable spray nozzles for high pressure water, lifting forks with individual spray nozzles and, suction tubes for retrieving slurry. Further, equipment for recovery of solids from slurry (hydrodynamic removal and decanting systems) will need to be developed in future.

8. SITE SECURITY AND SAFEGUARDS

The DGR facility will employ security measures for physical protection of nuclear material and the nuclear facilities in order to prevent unauthorized removal and sabotage of nuclear material in use and in storage at the facility. The DGR facility will have safeguards measures which will provide credible assurance of non-diversion and the absence of undeclared safeguards relevant activities.

8.1 SITE SECURITY

The interior section of the surface facilities as well as that area around the Ventilation Shaft Complex will be considered Protected Areas per current Nuclear Security Regulations (SOR/2000-209). The Protected Area boundaries will consist of a physical protection system, with controlled personnel and vehicle access points. Furthermore, the entire surface facility will be surrounded by a fence in order to provide controlled access to vehicles and persons and to prevent intrusion of wildlife.

The Protected Areas physical protection systems will incorporate a perimeter barrier with unobstructed land of minimum 5 m clear distance on both sides of the barrier. In addition, a system of protective elements will be in place to provide multiple layers of delay, detection and assessment that are controlled through a central command post or security monitoring room. The assessment component will enable security personnel to evaluate detected threats and provide the appropriate response. All of these component layers will further be connected to a back-up uninterrupted power supply, located within the Protected Area.

Nuclear Security Regulation (SOR/2000-209) stipulates that the detection and assessment components must each feature two independent systems. The delay component must have additional capabilities to deny intruders using large vehicles from forcing entry. Consistent with these requirements, the systems established to secure the Protected Areas will include:

- A physical barrier to delay intruders for a sufficient period of time to enable effective interception by response personnel and provide sufficient time delay at all points around the perimeter of the facility;
- A detection system to identify intruders immediately and alert security and response personnel; and
- An assessment system, with a dedicated lighting network, to allow security personnel to clearly identify and quantify any possible intrusion.

The various aspects of the site security infrastructure, including those for the Protected Areas, are discussed in this section. For illustrative purposes, their locations in the DGR facility have been shown in the following Figure 58.

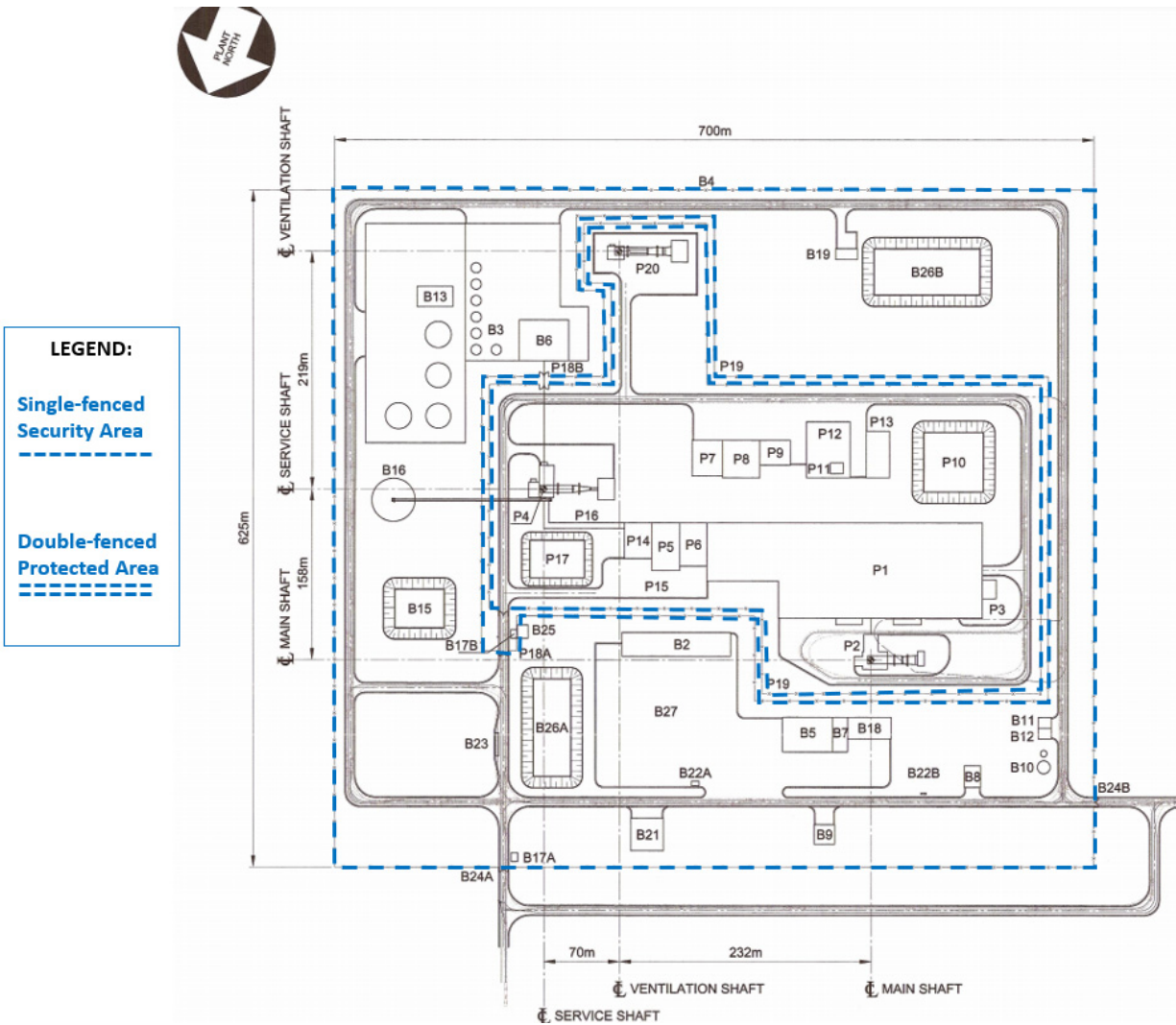


Figure 58: Site Security Components

8.1.1 Security Monitoring Room Area B25

The main security monitoring room will house monitoring equipment including cameras and closed-circuit TV monitors and will serve as the central command point for security surveillance serving both the Protected Areas and the Balance of Site. The security room (Area B25 in Figure 58), located adjacent to the Administration Building, will accommodate four on-duty personnel per shift. Remaining security team members will be on standby in the event of an emergency.

8.1.2 Physical Barrier Systems

There will be two security fence systems in place at the DGR facility. While a double fence (Area P19 in Figure 58) will surround the Protected Areas, a separate perimeter fence (Area B4 in Figure

58) will act to contain essentially all of the DGR's surface facilities, excluding the separately enclosed Ventilation Shaft Complex (Area P20 in Figure 58).

8.1.2.1 Protected Area Security Fence Area P19

A physical barrier system will be constructed to restrict unauthorized access by employees and visitors to the facilities in the Protected Areas. As illustrated on Figure 59, there will be two fences; one inner and one outer barrier each 3 m high above grade. The fences will be set 3 m apart with coils of barbed wire placed in between over a gravel surface. Lighting and monitoring will be in place as discussed below. The ground will be cleared to provide an unencumbered setback of 5 m on either side of the fence to permit visibility and provide moving room for patrol vehicles. Posted signs will identify the restricted access.

In addition, supplementary capabilities will be established to deny intruders using large vehicles access to the main Protected Area. While jersey barriers may typically be used for such purposes, a structure similar to that illustrated on Figure 60 will be installed at the vehicle access point. Two pairs of these movable gates will be established, separated by a space (sally port¹) sufficiently large to accommodate any vehicle entering the Protected Area.

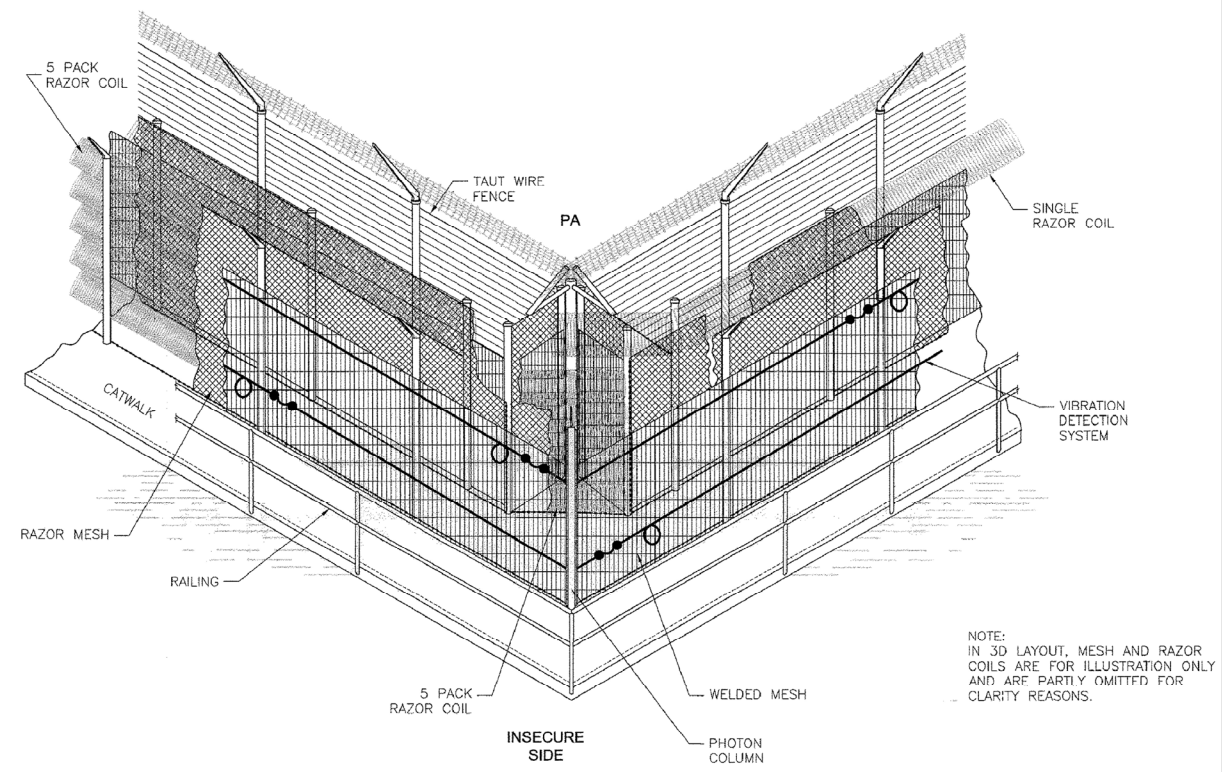


Figure 59: Protected Area Security Fence

¹ A sally port is an intermediate holding area for incoming vehicles. The vehicles are contained by two sets of gates for inspection and clearance.



Figure 60: Vehicle Entry Point

Protected Area Detection System

To detect intruders attempting to gain access into the Protected Areas the following sensor systems will be established:

- Photon sensors installed immediately outside the outer fence to detect and alert security personnel that an intruder is attempting to climb the fence;
- Shaker sensors installed on the outer fence to detect and alert personnel that an intruder is attempting to climb the fence; and
- A taut wire fence 3 m high and located 4 m away from the main fencing including a guy wire and detectors to alert security that an intruder is attempting to gain access.

Protected Area Assessment System

To assess alarm signals sent by the Protected Areas detection system sensors, the following will be in place:

- Each sector of the assessment system will have one dedicated CCTV camera installed on a pole. Every two sectors will have a camera with pan, tilt and zoom capabilities;
- Every two sectors will have one dedicated infrared camera to assist security personnel during poor weather and visibility conditions; and
- An auxiliary remote wireless surveillance camera mounted on the highest point of the facility will compensate for any deficiencies of the preceding equipment.

The installed cameras will be supported by lighting systems situated inside of the Protected Areas' boundaries that are capable of providing the required illumination levels. Additionally, secure mobile phones and satellite phones will permit secure lines of communication between security personnel.

The coordination of these security functions will be carried out through the security monitoring room.

Protected Area Entry Control System

Personnel access to the facility's Protected Area will also be controlled by several integrated security features. These could include entry turnstiles controlled by hand geometry identifiers and exiting turnstiles controlled by a radiation portal monitor. Explosive detectors as well as metal detection devices for personnel and personal articles will additionally be installed. Figure 61 provides an illustrative example of such a system.



Figure 61: Example of Entry Control System

8.1.2.2 Balance of Site Perimeter Fence Area B4

An additional fence will act as a site demarcation (perimeter) feature for the DGR facility while also providing a barrier / deterrent to intruders, including large animals. Entry through the fence will be by the facility access road from the incoming highway. While free access will be provided through this point, 'cattle grates' may also be incorporated to deter large animal entry. The ground will be cleared (minimum 5 m distance) to provide an unencumbered setback on either side of the fence to allow for unrestricted visibility and as a route for future maintenance. Signs will be posted on the fence indicating the purpose of the facility, and its restricted access.

The fence will consist of a 3 m tall, galvanized chain link wire, of heavy gauge construction. Access gates will be of the automatic sliding metal chain link type, with a secondary lift-up barrier. Gates will be controlled by security personnel at the guardhouses and be monitored by the main security monitoring room.

8.1.3 Security Checkpoints and Guardhouses

Several access control points and guardhouses will be established at the DGR facility, as illustrated on Figure 58. These are discussed below.

8.1.3.1 Security Checkpoints Areas P18A, P18B, B24A & B24B

Access to the Protected Areas will be strictly controlled, as discussed above. Regular staff will enter through controlled systems and all visitors, after registering with security staff, will be accompanied by authorized staff members when in the Protected Areas. The adopted system will be capable of tracking personnel into and out of the Protected Areas and maintaining an electronic list of on-site personnel and their locations.

Two Protected Area access control points are to be established; one will allow for vehicular traffic and personnel and the other serves as materials access identified as Areas P18A and P18B respectively on Figure 58. The access control points are described below:

- Checkpoint P18A – will serve as the main vehicular and personnel access point to the Protected Area, and the gate through which the incoming used fuel shipments will pass. This checkpoint will utilize a manned security booth for traffic control and inspections and will provide barriers to deny intruder entry using large vehicles; and also, will provide access to the Auxiliary Building (Area P5). This checkpoint will utilize a manned security station, turnstiles and biometric identification systems for personnel control, with an auxiliary access gate for equipment;
- Checkpoint P18B – will allow access for materials from the Sealing Materials Compaction Plant (Area B6). A manned security booth will be in operation during active hours for the transport of materials to the Service Shaft Complex (Area P4). Personnel access will not generally be through this checkpoint.

Access control points for the Balance of Site will be provided for general security concerns only, such as theft, vandalism, animal intrusion, and general liability (safety). Personnel and vehicular access to the Balance of Site will be controlled through access gates. Two control points will allow for vehicular traffic. Located as indicated on Figure 58, they include:

- Checkpoint B24A – will act as the main access point to the DGR facility. All facility traffic will pass through this point. While the gate will be able to be locked, its status will be controlled by the adjacent guardhouse (Area B17A); and
- Checkpoint B24B – will act as a secondary or contingency access point if needed. Traffic through this area is expected to be minimal, therefore a manned security booth will not be required. Access will be by key and lock.

8.1.3.2 Guardhouses Areas B17A and B17B

In addition to the checkpoints described above, two guardhouses will be provided for security personnel for the control, verification and authorization of vehicle and staff movements into and out of the DGR facilities.

The first guardhouse will be located at the main entrance to the Balance of Site (Area B17A on Figure 58). A second station will be situated at the entry control point for the Protected Area (Area B17B). Both guardhouses will accommodate a control room and security desk. A secure staging area for vehicles (a sally port) will be provided adjacent to the Area B17B station.

8.2 SAFEGUARDS

The purpose of safeguards measures is to provide credible assurance of non-diversion and the absence of undeclared safeguards relevant activities as prescribed by the IAEA. In the DGR facility, this would be accomplished through nuclear material accounting techniques (to maintain knowledge of the contents of each package) and a containment and surveillance system (to verify the continued integrity and movements of the spent fuel packages to maintain the continuity of knowledge on them). An important aspect of the safeguard system is the security measures. The security measures will provide physical protection of nuclear material and nuclear facilities in order to prevent unauthorized removal and sabotage of nuclear material in storage. Security measures will include technical means and procedures of access control, detection of unauthorized intrusion and response to unauthorized intrusion.

9. OPERATIONAL SAFETY AND MONITORING

The following section addresses operational safety and monitoring initiatives that will be enacted at the DGR facility. The described initiatives have been identified both from a best practice perspective, as well as to meet the objectives set out in domestic and international regulatory and guidance documents (e.g., Canadian Nuclear Safety Commission, International Atomic Energy Agency, etc.).

Conceptual-level design details are provided herein for radiation detection and monitoring systems, fire detection and suppression, facility environmental and performance monitoring, and emergency response procedures.

9.1 OPERATIONAL SAFETY

An occupational health and safety program will be in place and implemented for all periods in the evolution of the DGR when there are workers actively involved. As the project's components involve underground construction and operation as well as the handling of used nuclear fuel, there are significant industrial and radiological components to the program.

9.1.1 Radiological Protection

An important component of the occupational health and safety program will be the radiation protection program. The radiation protection program will comply with the requirements and regulations of the Canadian Nuclear Safety Commission (CNSC). It will describe a set of standards, procedures and reports to ensure that contamination levels and radiation doses received by individuals are monitored, controlled and maintained as low as reasonably achievable (ALARA), taking into account social and economic factors (CNSC, 2019). The facilities will contain the systems, infrastructure and equipment required to support the radiation protection program and ensure effective application of the ALARA principle. Shielding design criteria are discussed in Section 2.2.6.

All protected areas within the APM DGR facilities' fence will be zoned according to their potential for exposure to external sources, airborne hazards, and loose contamination on surfaces. Four radiation hazard zones have been assigned to various areas of the facility, as noted below.

9.1.1.1 ZONE 1

Zone 1 will be a normally occupied area that is accessible to all staff. As there will be no potential for contamination, Zone 1 areas are considered to be "clean" areas. The dose received by an individual from external radiation sources during continuous occupancy of a Zone 1 area is not to exceed the recommended annual limit to the public in one year. Apart from natural background levels of radioactivity, no other radioactive contamination will be present in this zone.

Zone 1 space will typically include offices, access corridors, lunch / coffee rooms, site lands and roadways. In terms of the DGR facility, the identified 'Balance of Site' (that is, all locations outside of the Protected Areas) will be considered Zone 1.

9.1.1.2 ZONE 2

Zone 2 will normally be free from contamination, except for infrequent cross-contamination from the movement of personnel, materials and equipment from contaminated zones. Chronic recurrences of contamination in Zone 2 will not be tolerated. Continued occupancy of Zone 2 operations will be restricted to Nuclear Energy Workers (NEW), as specified in the Radiation Protection Regulations (SOR/2000-203), with controlled access to those not designated as NEWs.

Generally, all areas with operations with sealed UFTPs and UFC/Buffer Box Transfer Casks within the surface Protected Areas and all underground repository areas, except the placement rooms, will be Zone 2 areas. The underground repository is currently considered to be Zone 2 because the integrity of the UFCs and associated administrative controls will prevent the release of radioactivity.

9.1.1.3 ZONE 3

Zone 3 areas will be normally unoccupied by NEWs. These areas have the potential for contamination because they contain systems and equipment that may be sources of contamination. Controlled access is required for entry by NEWs into Zone 3 areas, along with planned exposure control measures (e.g., protective clothing, respiratory protection, work planning, etc.).

Depending upon the final design details, the only Zone 3 areas associated with the DGR facility will be within the UFPP.

9.1.1.4 ZONE 4

Zone 4 areas will be for hot cells. They are normally inaccessible to NEWs and contain unsealed sources or high radiation fields. All hot cells within the DGR facility will be located in the UFPP and will be designated as such if they have unshielded used fuel sources (e.g., UFTP unloading cells, UFC loading cells, UFC processing cells, etc.).

Surveys and monitoring of the facility will be used to control the spread of contamination and to ensure that radiological conditions at the facility are safe. Routine surveys will be performed to ensure that facility conditions remain constant, that all hazards are identified, and that signage and postage are up to date. In addition, task-specific monitoring and surveys will be performed if deemed necessary during work-planning.

In support of the survey and monitoring requirements, the facility will be equipped with surveying and monitoring instrumentation with alarm settings as required. The system will incorporate the following features:

- Hand and foot monitors, whole-body monitors, small article monitors or portable radiation detection instruments to monitor the movement of personnel and materials across the boundary of radiological control areas into an area of decreased potential for contamination (e.g., from Zone 3 to Zone 2);

- Fixed area gamma monitors located throughout the facility to gauge local dose rates at places routinely occupied by operating personnel;
- Air radiation monitors located throughout the facility, including the exhausts for ventilation systems;
- Radiation vehicle monitors (portable and fixed) at entry or unloading areas; and
- An uninterrupted power supply will be provided for all devices required by the detection and assessment systems (in addition to any associated alarm annunciations).

Doses of radiation will be ascertained and recorded as part of the Radiation Protection Program. A licensed dosimetry service will be used to measure and monitor the doses of personnel who have a reasonable probability of receiving a dose greater than 5 mSv in a one-year dosimetry period. Exposure to naturally occurring radioactive substances (i.e., radon) that result from NWMO activities will also be included in the assessment of doses.

In support of the dosimetry program, the facility will be equipped with the following:

- The use of dosimeters (i.e., thermo-luminescent dosimeters) and direct-reading devices (i.e., electronic personal dosimeters) as appropriate by staff, contractors and visitors; and
- Whole-body counters for annual or quarterly use.

A system will be established to detect, monitor and record any airborne or waterborne releases of radioactivity leaving the site. Before the start of operations, environmental programs will establish baseline conditions at the site for naturally occurring radioactivity (e.g., for naturally occurring radon and uranium) to help differentiate the radiological impact caused by the facility. Further details are provided on the Environmental Monitoring Program in Section 9.2.

9.1.2 Monitoring for Radioactive Releases

A system will be established to detect, monitor and record any airborne or waterborne releases of radioactivity leaving the site. The system will be implemented with the goal to align with the ALARA principle. Prior to start of operations, environmental programs will establish baseline conditions at the site for naturally occurring radioactivity (e.g., for naturally occurring radon and uranium) to help differentiate the radiological impact caused by the facility. Monitoring of releases and of environmental contamination will continue through operations. See Section 9.2 for further details on the Environmental Monitoring Program.

A licensed dosimetry service will be used to measure the radiation dose to all employees who have a reasonable probability of receiving a recordable effective dose due to work at the facility. This exceeds the requirements of the Radiation Protection Requirements, which require the use of a licensed dosimetry service to measure the doses to all employees who have a reasonable probability of receiving an effective dose of 5 mSv or greater in a year.

9.1.3 Fire Detection and Suppression

The following discussion focuses on the underground systems to be put in place as related to fire detection and fire safety. An optimum suppression concept that balances worker and nuclear safety will be established.

The underground portion of the DGR facility will have the following fire protection features:

- Suitable fixed fire suppression systems and portable fire extinguishing equipment in any fire hazard area;
- Fire extinguishing equipment in the mine entrance and at shaft stations; and
- Permanent and portable refuge stations with safety apparatus like breathing equipment, emergency air systems and communication devices to be used by underground workers during emergencies.

In addition, fire detection systems incorporating heat, smoke and carbon monoxide detectors at key points in the facility will also be set up. Key locations for fire detection equipment will include all underground infrastructure rooms, the exhaust ventilation air ducts exiting each placement room, the intake duct for the Main Shaft, and at the main exhaust ducts of the upcast Exhaust Ventilation Shaft. Audible and visual alarms will be activated on detection by any instruments required to do so. A stench gas system will also be used to notify underground workers in the event of an emergency.

All underground vehicles will also be fitted with fire detection and suppression equipment. In total, fire suppression will be achieved through the use of a number of systems both for the equipment and the underground environment. Systems will include the following:

- Hand-held foam-based fire extinguishers mounted throughout the facility;
- Automatic, foam-based fire suppression systems mounted on all heavy equipment;
- An inert gas generator and a portable foam generator for extinguishing any fires that develop in the placement rooms;
- Normal sprinkler and/or fire hose systems for areas where appropriate;
- A water spray deluge system for hazardous environments where fires may spread very quickly or where valuable materials need to be cooled; and
- A water mist system for areas where appropriate.

Breathing air requirements as prescribed by regulatory guidelines and worker health and safety protocols (as applied to firefighting, non-nuclear air contamination, etc.) will be followed.

9.1.4 Emergency Response and Mine Rescue

Procedures for emergency response planning, the notification of releases and incident reporting will meet CNSC requirements and include the utilization of incident command systems to meet the needs of any kind or complexity of situation. For severe incident management (e.g., extreme or violent weather, chemical spills, etc.), various emergency related resources will be available. These will include:

- Pre-planned response procedures (including shutdown protocols);
- Pre-established post-emergency procedures including those for resuming operations;
- Off-site and on-site communications and management protocols, including regulatory notifications and public interaction;
- The services of an Emergency Response Team (ERT) or Mine Rescue Team (MRT); and
- Pre-trained staff that have undergone regular training on emergency response issues.

The primary personnel involved in handling any emergency will reside within an ERT/MRT. These resources would also be supported by on and off-site firemen and first aid attendants as well as

the DGR's various superintendents and shift managers. Communications staff will be available to coordinate and assist in the required incident communications activities.

Emergency response requirements have been incorporated in the design of the facility (e.g., fire protection and suppression, egress and refuge, secondary repository egress, etc.) as well as identification of services to support response (e.g., mine rescue, fire rescue) for the various phases of the DGR.

9.2 ENVIRONMENTAL MONITORING PROGRAMS

Prior to the start of construction, the environmental monitoring program will collect data to establish baseline conditions. Thereafter, the program will monitor for any changes that may be imposed on the environment due to construction activities and ultimately the operation of the DGR facility. Monitoring requirements for the postclosure period will need to be re-examined as part of the final plan for decommissioning and closing the site.

The environmental monitoring program will be comprised of the following components:

- Radiological monitoring;
- Groundwater quality and levels monitoring;
- Monitoring of surface water and stormwater;
- Air quality monitoring; and
- Meteorological monitoring.

The following sections address each of the program components. The final elements will be developed as part of the formal licensing process for the DGR. The expectation is that the program will provide reliable, accurate and timely data in a fashion that is easily audited.

9.2.1 Radiological Monitoring

As a nuclear facility, radiological environmental monitoring will be established around the site as required to support compliance with the licensing conditions, which may include the Canadian Standards Association (CSA) Standard N288.4, Environmental Monitoring Programs at Class 1 Nuclear Facilities and Uranium Mines and Mills.

9.2.2 Groundwater Monitoring

Baseline hydrogeological studies will establish a conceptual groundwater system model that will describe site-specific properties, hydrostratigraphy and system behaviour. From the groundwater system model, features will be identified that should be monitored during the construction and operation of the DGR facility. Such features will encompass the groundwater regime at the DGR site, as well as any nearby community or individual water supply wells.

Potential groundwater impacts arising from operation of the DGR could include localized influence on near-surface groundwater flow patterns and/or the potential for non-radiologic contamination from, for example, chemical or fuel oil spills. Monitoring well locations will include those installed to characterize and establish baseline site conditions and those installed during the construction phase. In total, the monitoring well network is anticipated to be up to 100 wells. The wells will be

positioned within key sub-surface pathways both up- and down-gradient of potential on-site contaminant source areas (e.g., the excavated rock storage areas and on-site ponds) to allow reliable monitoring and detection of potential groundwater impacts, if any.

Representative water supply wells for any proximate community, as well as strategically positioned points between these and the DGR site, will also be included in the program.

Groundwater parameters monitored will include those related to groundwater flow (i.e., hydraulic head) and quality (i.e., non-radiologic; radiologic). Groundwater samples will be collected and analyzed on a quarterly basis. Assessment of groundwater quality impacts would be performed annually with 5-year reviews conducted to assess monitoring program adequacy and effectiveness.

9.2.3 Stormwater / Surface Water Monitoring

Stormwater runoff from the developed site (roads, parking areas and rooftops) can lead to increased flows and downstream erosion. Stormwater management ponds are designed to attenuate the variations in flow conditions while also being designed to detain and settle out sediments associated with runoff. They will also provide retention to allow sampling to confirm effluent limits are met prior to discharge and accommodate some emergency storage in the event effluent limits are exceeded and discharge is not allowed.

The monitoring program will be focused on the measurement of flows and water quality at the pond discharge points to confirm that water quality meet limits set in permits for the ponds. In the remote event that pond discharge water quality is found to exceed the limits then corrective actions will be taken to ensure the maintenance of regulatory compliance.

Pond water samples will be analyzed for a full suite of conventional parameters including anions and cations, metals, oil and grease and nutrient compounds. Sediment samples will additionally be collected from each pond and analyzed for trace metals, polychlorinated biphenyls (PCBs), polycyclic aromatic hydrocarbons (PAHs), organochlorine pesticides, total organic carbon, nutrients, and oil and grease.

Grab samples from the inlet and outlet of each pond will be examined for the identified parameters on a regular basis and as required by the permit for these facilities. Sediment samples will be assessed on an annual basis.

The monitoring program will also encompass surface watercourses and bodies outside the DGR site footprint and at nearby communities. Sampling locations will be selected to characterize water quality and flows both upstream and downstream of the DGR site in the local watersheds. Gauging locations will further be established to measure surface water elevations and flows. Water quality and hydrologic conditions will be monitored using both automatic and manual sampling techniques.

9.2.4 Conventional Air Quality Monitoring

For the above-ground environment, ambient air quality monitoring locations will be established both in the predominant downwind direction of the facility (including one at the nearest community)

as well as upwind of the site. The underground ventilation system will be exhausting into the atmosphere and thus it will be necessary to monitor potential discharge impacts on the local air shed.

The air quality in the underground repository will be monitored, the underground air monitoring equipment will include hand-held instruments (see Figure 62) as well as in-situ continuous emission monitoring devices.



Figure 62: Manual Air Quality Monitoring

9.2.5 Meteorological Monitoring

A weather monitoring station will be installed and operated at the DGR site. Using tower-mounted instrumentation, the station will provide site-specific and continuous meteorological data to assist in the ongoing operations of the facility. Real-time measured parameters will include:

- Ambient temperature;
- Relative humidity;
- Dew point;
- Barometric pressure;
- Wind speed;
- Wind direction;
- Rainfall; and
- Solar conditions.

9.3 SEISMIC AND VIBRATION MONITORING

Earthquake ground motions could occur during the operating life of the DGR facility. To provide adequate protection for workers, the public and the environment, the DGR facility will be designed to withstand the effects of a potential strong earthquake ground shaking at the site.

A regional seismic monitoring network will be established prior to start of construction to collect seismic data. These data combined with historic seismic data will be used to assess the seismic hazard at the proposed DGR site and will provide data for the seismic design of the DGR facility. The seismic monitoring will continue to operate during the operating life of the DGR facility for the purpose of confirming that risk of unacceptable earthquake ground shaking event is still low.

Ground vibration or movement is a commonly examined characteristic at underground mines. Ground vibration may occur due to blasting or due to failure within rock mass as result of stress redistribution around rock excavations. Significant ground vibration events are not anticipated at the DGR site because site selection criteria are favouring sites that have large masses of

competent rock. In any event, a series of geophones will be installed to create an underground vibration monitoring system. This system will be used to confirm any vibrations that are sensed are well below acceptable levels at key underground locations (e.g., placement rooms receiving UFCs). A series of geophones will be grouted into short boreholes drilled into the roof and floor of the underground openings at repository level and into the shaft sidewalls at various elevations. A typical geophone is shown in Figure 63.



Figure 63: Geophone

9.4 GEOTECHNICAL MONITORING

Geotechnical monitoring will be performed during the construction of the underground repository openings to measure and confirm in-situ rock behaviour. Rock movement and changes in rock stress will be monitored at selected locations as follows:

- **Rock Movement Monitors:** extensometers will be installed within short boreholes in the shaft walls and the roofs of underground rock openings to monitor for rock movement; and
- **Stress Cells:** stress cells will be installed within the concrete shaft liner and at the rock / concrete shaft liner interface. Stress cells will be installed in the roofs of underground rock openings to measure any changes in rock stress as a result of excavation work and/or heating of rock due to heat loading by the UFCs.

9.5 QUALITY ASSURANCE / QUALITY CONTROL FOR MONITORING

Quality assurance / quality control procedures will be implemented throughout the monitoring programs to ensure thoroughness and accuracy of the data. In this regard, the programs will include the following measures (among others) to ensure a high degree of confidence in the collected information:

- Strict adherence to standard protocols for the collection, preservation, storage, handling and shipping of samples and for in-situ sampling;
- A field quality control program, including the submission of travel and field blanks and duplicate samples;
- Implementation of a quality control program for the laboratory analyses; and
- Timely review of analytical results to identify areas of concern (including potential impacts).

Annual and quarterly status reports will be prepared to summarize the activities as related to the environmental monitoring program. The results of the ongoing QA/QC activities will be incorporated in these reports.

9.6 CENTRAL TAGGING SYSTEM

A central tagging system will be put in place at the DGR facility to monitor the movements and quickly locate all facility personnel, equipment and tools (including radiation-impacted objects). The system will be coordinated out of a central control area which will receive wireless signals from transmitting / receiving devices assigned to on-duty personnel and installed on each facility vehicle or asset. Conceptually, the tagging system will operate as follows:

- A wireless tag will be provided to a person and/or attached to a piece of equipment when entering the DGR facility check-in point;
- As the person / equipment moves through the DGR facility, the associated tag is read by other multiple wireless readers positioned in various locations in the facility;
- In terms of hard assets, once the item reaches its destination, a tag reader will allow a cross-check to be made to confirm that it is supposed to be at that location;
- Items incorrectly received will be flagged for removal and re-routed; and
- When an item or person leaves the facility, the associated wireless tags are read at the exit point.

This tracking system will assist operational personnel and increase worker safety. It will also allow for the remote management of all assets by identifying their exact location.

In the underground environment, the collected data will be transmitted using a leaky co-axial and fibre optic system, which will relay information from the source instrument or electronic device to the surface control room. As illustrated on Figure 64, such a system consists of cables running along the tunnels and in shafts which emit and receive digital transmissions. The digital information is transmitted by fibre optic cable.

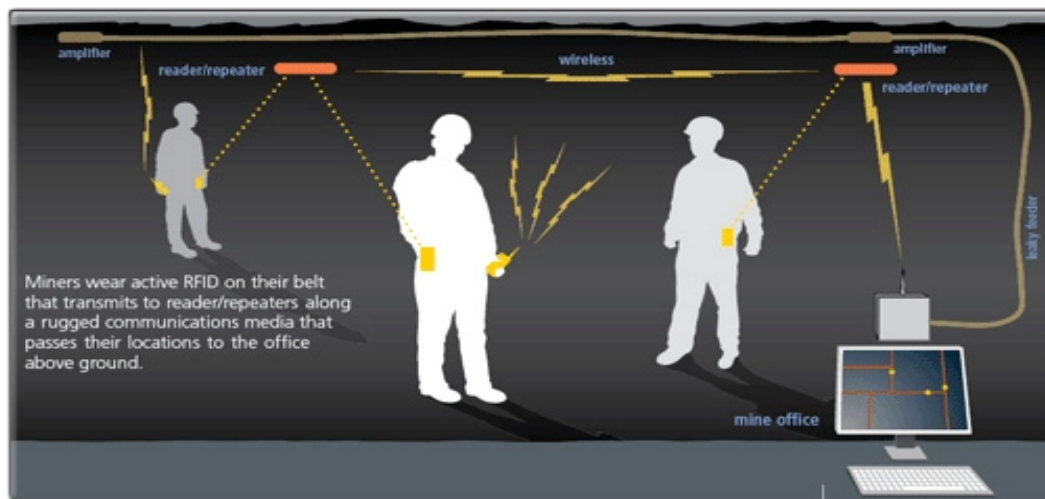


Figure 64: Typical Wireless System for Underground Mining Operation

10. DECOMMISSIONING AND CLOSURE

Subsequent to the cessation of used fuel placement activities and the 70-year extended monitoring period, the following series of actions will take place:

- 10-year decommissioning period;
- 15-year closure period; and
- Postclosure period.

These activities are the subject of this section, following a brief discussion of certain key issues that will impact upon the decommissioning and closure (D&C) work and the staged, progressive development of D&C planning. Actions undertaken during the D&C period will be designed to return the selected site and related facilities to the desired end-state. As discussed below, such planning will commence with the preparation of a Preliminary Decommissioning Plan structured to meet the requirements of REGDOC-2.11.2 (CSNC, 2021b), Decommissioning, and CSA Standard N294-09 (R2014), Decommissioning of Facilities Containing Nuclear Substances.

10.1 KEY ISSUES

Several issues have the potential for a material impact to D&C planning and implementation. Such issues include the final site selection, the status of container retrieval initiatives, the potential for advancements in associated technologies, and the direction received from regulatory bodies. These factors are outlined below.

10.1.1 Container Retrieval

The possibility for future container retrieval has a potential major impact on the implementation and staging of D&C activities. For example, a decision following completion of placement activities to forego the possible retrieval of buffer boxes (with UFCs) would allow a number of surface facilities to be decommissioned near the start of the extended monitoring period. On the other hand, under the approach that the potential for retrieval must remain open during the 70-year extended monitoring period, many surface and underground facilities will need to be inspected and maintained over the full 70-year period (or until a decision has been taken that the ability to retrieve buffer boxes is no longer required).

10.1.2 Advancements in Associated Technologies

The described initiatives within this section have been identified from, in part, a current best-of-practice perspective and feasibility perspective. Decommissioning and closure activities will occur in the future (in excess of 100 years from now) and it is likely that new technical solutions will be available at that time. These new solutions would be considered and, if appropriate, used to decommission and close the DGR facility.

10.2 PLANNING FOR DECOMMISSIONING AND CLOSURE

Major decommissioning and closure activities include the following:

- Initial preparation of the Preliminary Decommissioning Plan near the start of preliminary design at the preferred site. Progressive updates over the course of the preliminary and detailed design stages of work, as well as for the period of used fuel placement. The maintained and updated plan will support periodic licence renewals throughout the DGR operations based on current codes, regulations and standards and incorporate relevant advances in technology. The plan will evolve throughout this period to continually represent the current as-built status of the facility, and operational and maintenance experience gained during placement;
- Following operations and at the commencement of the 70-year extended monitoring period, a material revision to the Preliminary Decommissioning Plan will be made. The plan will be subject to a special detailed review in order to finalize requirements for the extended monitoring period. As a significant portion of the effort spent during the extended monitoring will be focused on the design of facilities needed to support decommissioning and closure, this review will assist in providing directions and recommendations for this work. Several key parameters that may be monitored for an extended period are rock temperature, rock stress / displacement (response to thermal loading), water ingress, emplacement room seal performance, ground water quality, ground water radioactivity, humidity and acoustic emissions. This revision will be progressively updated over the course of the extended monitoring phase. Any updates would consider experience gained, as well as regulatory or technology updates. The evolving D&C plans will also provide updated directions and recommendations for facility maintenance or even early removal and disposal of component operations, where appropriate;
- Another material revision to the plan will be made prior to the commencement of the 10-year decommissioning period, using information collected during extended monitoring phase. The resulting Detailed Decommissioning Plan will support the application for regulatory approval to start decommissioning and closure work. The plan will be based on a fully defined methodology and procedures for implementation. It will form the basis for contracting and managing the implementation activities. Progress reports would be published over the course of the decommissioning stage;
- Assembly of the final material revision to the plan will be made at the start of the 15-year closure period, based on information collected to that point in time and documenting the results of the decommissioning work. Progress reports would also be produced during the closure period; and
- Preparation of a postclosure report documenting the results of decommissioning and closure activities.

Regular maintenance of the evolving D&C plans will help ensure that the site programs and designs remain consistent with up-to-date and relevant internal / external decommissioning experience. It will also act to ensure that licensing and other regulatory requirements are continually met with regards to site safety, security and access control needs.

The D&C plans will all be designed, prepared and maintained to achieve the return of the site and related facilities to the desired end-state.

10.3 DECOMMISSIONING AND CLOSURE OF UNDERGROUND FACILITIES

Following the receipt of regulatory approval and the licence to decommission and close the DGR facility, underground facilities are expected to be removed first, in parallel with those surface facilities not required to support the remaining underground decommissioning and closure activities.

Decommissioning of underground facilities will involve the removal of operational systems and furnishings, the interim installation of temporary services and furnishings, and the repair and preparation of exposed rock surfaces for sealing. As currently envisaged, the decommissioning and closure activities will be carried out in several stages and will include activities related to removal of ground support (if feasible) and material handling systems, the sealing of underground horizontal openings, and the sealing of shafts and boreholes.

10.3.1 Sealing of Underground Horizontal Openings

The sealing of underground horizontal openings will consist of closing off access tunnels and ancillary facilities. Such activities would commence with the removal of instruments from boreholes (and sealing the boreholes) followed by the preparation of exposed rock surfaces and removal of loose rock before backfilling and sealing. The central access tunnels would then be backfilled, with sealing bulkheads installed at strategic locations where conditions dictate.

The key functional requirements for various components of sealing system will be as follows:

- Fill the entire excavated volume of each area being sealed;
- Resist physical and chemical deterioration by the local environment, which includes the preclosure and postclosure geochemical conditions;
- Limit the rate of groundwater flow to and from the sealed placement rooms; and
- Limit rate of potential radionuclide migration from placement room and, if released from rooms, radionuclide migration along various underground tunnels and within the shafts.

Sealing of the underground openings will be achieved by using materials and methodologies similar to that used within the placement rooms. The clay-based fill material would occupy most of the underground tunnel space. At strategic locations seals comprised of HCB blocks would be constructed which would be complemented by a concrete bulkhead. These bentonite seals and concrete bulkheads would likely be installed near access tunnel intersections and also near intersections with significant zones (as appropriate).

The key functional requirements for the concrete bulkheads will be to provide mechanical restraint against the forces exerted by swelling clays or pressures from other repository sealing systems, the surrounding rock mass or other sources. The bulkheads will further act to keep the sealing

materials isolated in their intended locations and protected from any adverse conditions that may exist in adjacent unsealed excavations.

The sealing of the access tunnels will be carried out ensuring that the required tunnels are maintained open to provide ventilation to working areas. Therefore, the sequence for tunnel closures will consist of sealing all tunnels in a retreating manner from the Exhaust Ventilation Shaft to the Service Shaft. Local ventilation systems using portable exhaust fans and duct tubing will be exhausted into the flow-through ventilation system. Periodic crossovers between the tunnels will be used to provide flow through ventilation and to draw air from the work areas.

10.3.2 Sealing of Shafts

Sealing of the shafts is the last step in the closure of the DGR. This activity starts when the sealing of underground openings and ancillary areas is complete. At that time, the following activities are envisioned:

- Removal of shaft services including compressed air lines, water lines, power supply and lighting cables, and communication cables;
- Removal of instruments from any impacted boreholes and sealing of each borehole;
- Removal of furnishings including all of the shaft guides and sets, steel support brackets, brattice and lower crash beam assemblies from bottom to top while backfilling; and
- Reaming of the shafts (as required) to remove the concrete linings and any highly damaged wall rock.

Thereafter, each shaft will be re-equipped with services and staging, and backfilling will commence with sealing bulkheads installed at strategic locations.

A generic shaft seal design is presented in Table 19 and shows a shaft seal for the nominal 500 m repository depth. The design assumes removal of 500 mm-thick annulus of highly damaged rock before sealing materials are placed and the concrete bulkhead is keyed into the rock in a conical shape to a depth of 0.5 times the radius of the shaft. The repository depth will be between 500 - 800 m and the shaft sealing design will be updated in each region to suit site specific geologic conditions as site investigations continues.

Table 19: Generic Shaft Seal Design

Component Depth	Shaft Seal Component
0 - 20 m	LHHPC – concrete cap at surface
20 - 150 m	70/30 bentonite-sand shaft seal compacted in-situ
150 – 170 m	LHHPC for concrete bulkhead keyed into rock to a depth of 0.5 times the original radius of the shaft
170 – 330 m	70/30 bentonite-sand shaft seal
330 – 380 m	Asphalt seal
380 – 480 m	70/30 bentonite / sand shaft seal compacted in-situ
480 – 500 m	Concrete monolith - LHHPC

The shaft sealing system is based on the assumption that all shafts will intersect low permeability rock over the full depth of the shafts. However, it is possible that the DGR shafts will intersect relatively permeable rock near ground surface. If so, then engineered fill material based on rock excavated during shaft sinking or some other suitable material will be used in the upper portion of each shaft. This engineered fill would likely be placed from surface to a depth where low permeability rock is first encountered.

The shaft seal design concept has focused on the use of simple, relatively well understood and durable materials, and use of proven methodologies for placement. Concrete, bentonite/sand mixture and asphalt will be the sealing materials used in each shaft. Additional information about each major component of the shaft seal system is presented below.

Concrete monolith will be placed at the base of the seal system. Concrete will provide a stable foundation for the overlying seal materials. The monolith will be constructed in stages beneath each shaft. Each monolith will form a contiguous mass concrete structure with no structural reinforcement within the concrete. All services and utilities will be stripped out of the excavations to be filled by the monolith.

Bentonite/Sand Seal: The column of sealing materials in each shaft is largely composed of a compacted bentonite/sand mixture. Once saturated, the compacted bentonite / sand materials will act as a low permeability barrier to retard the movement of radionuclides out of the repository and minimize the potential for groundwater flow down into the repository. Compacted clays or clay/sand mixtures are the most commonly proposed sealing materials for nuclear waste repositories. Sand will be added to the bentonite to act as a filler without compromising the hydraulic conductivity and swelling potential of the bentonite dominant material. The use of sand will improve workability during placement, ease compaction and dust control. As the compacted bentonite/sand materials saturate with groundwater from the surrounding rock, they will generate swelling pressures, which will aid in the development of a tight seal against the shaft wall and provide a confining pressure to the rock surface.

Asphalt Seal: An asphalt column will be placed above the lowermost bentonite / sand column. Asphalt has been selected because it has the ability to flow and make good contact with host rock. Immediately upon emplacement, the asphalt will create an effective barrier to water flow. 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.

Concrete Bulkhead: The primary function of the concrete bulkhead will be to provide structural support in the column of sealing materials. In the short-term the concrete will act as an additional seal and over the long-term the ability to act as a seal will diminish as concrete degrades. As with the monolith, concrete for the bulkhead will be placed in mass and with no reinforcing steel and using measures to control heat build-up. Contact/seal grouting will be applied around the bulkheads to minimize the potential impacts of shrinkage at the interface with the host rock formation. Concrete will be poured directly onto the bentonite / sand columns located below each bulkhead.

Concrete Cap: A surficial concrete cap will be installed on each shaft to minimize risk of human intrusion into the underground repository via shafts. The cap will be constructed using concrete. Air entrainment within the concrete is required to minimize adverse effects of freeze/thaw action on the concrete cap.

10.3.3 Sealing of Boreholes

The purpose of sealing a borehole (e.g., monitoring boreholes) is to inhibit groundwater movement and contaminant transport along the borehole and in the near-field rock parallel to the borehole axis. Cement-based sealing materials will be installed where required to isolate fractured and highly permeable zones because of their low hydraulic conductivities and their groundwater resistance. Clay-based materials with low permeability and a high swelling potential will be installed in adjacent zones.

Sealing of boreholes is commonly practiced in the construction and resource industries to decommission water and monitoring wells. As the geological features intercepted by each borehole will not be identical, a thorough review will be conducted on all available core and borehole logs and down-hole test results to ascertain the preferred sealing approach for each location.

Investigation boreholes will generally be located outside the footprint area occupied by the underground repository. Exceptions would be investigation boreholes at each shaft locations.

10.4 DECOMMISSIONING OF SURFACE FACILITIES

During the 10-year decommissioning period, some supporting surface facilities will be dismantled and removed from the site. The surface facilities and related services will be evaluated and classified in the D&C planning to identify if they are required to support underground decommissioning and closure activities. The sequencing described in this section and suggested in Table 20, is based on an initial evaluation in this respect which resulted in the placement of each component or service in a comparative position on the decommissioning time queue.

In general, the majority of surface facilities will not be decommissioned until the underground operations have been dismantled and removed, with the access tunnels and shafts sealed as planned. These activities will be the primary focus for concrete and special sealing materials which require an operating surface facility and an underground hoisting operation.

Table 20: Surface Facility Classification for Decommissioning

Area	Protected Area	Primary Function	Comments
P1	Used Fuel Packaging Plant (UFPP)	UFC processing	Decommissioned with underground (U/G) facilities. Once no UFC retrieval is contemplated the UFPP can be demolished.
P2	Main Shaft Complex	Provide U/G access	Can be decommissioned as last step of U/G D&C.
P3	Stack	Related to UFPP	Will be decommissioned with the UFPP.
P4	Service Shaft Complex	Provide U/G access	Can be decommissioned as last step of U/G D&C.
P5	Auxiliary Building	Related to U/G access	Can be decommissioned as last step of U/G D&C.
P6	Active Solid Waste Handling Facility	Related to operation and decontamination	Will be decommissioned as part of Protected Area facilities.
P7	Waste Management Area	Related to operation and decontamination	Will be decommissioned as part of Protected Area facilities.
P8	Active Liquid Waste Treatment Building	Related to operation and decontamination	Will be decommissioned as part of Protected Area facilities.
P9	Low-Level Liquid Waste Storage	Related to operation and decontamination	Will be decommissioned as part of Protected Area facilities.
P10	Stormwater Management Pond	Related to total project	Will be part of closure activity.
P11	Switchyard	Related to total project	Will be part of closure activity.
P12	Transformer Area	Related to total project	Will be part of closure activity.
P13	Emergency Generators	Related to total project	Will be part of closure activity.
P14	QC Offices and Laboratory	Related to total project	Will be part of closure activity.
P15	Parking Area	Related to total project	Will be part of closure activity.
P16	Covered Corridor / Pedestrian Routes	Related to total project	Will be decommissioned consistent with connected structures.
P17	Mine Dewatering Settling Pond	Related to decommissioning of U/G	Cannot be decommissioned until U/G decommissioning is complete.
P18	Security Checkpoints	Related to total project	Will be part of closure activity.
P19	Double Security Fence	Related to decommissioning of U/G	Cannot be decommissioned until U/G decommissioning is complete.
P20	Ventilation Shaft Complex	Related to U/G access	Can be decommissioned as last step of U/G D&C.

Area	Balance of Site	Primary Function	Comments
B1	Excavated Rock Management Area	Related to total project	Will be part of closure activity.
B2	Admin. Building, Firehall, Cafeteria	Related to total project	Will be reconfigured as part of closure activity.
B3	Sealing Material Storage Bins	Related to decommissioning of U/G	Cannot be decommissioned until U/G decommissioning is complete.
B4	Perimeter Fence	Related to total project	Will be part of closure activity, possibly reconfigured.
B5	Garage	Related to total project	Will be part of closure activity.
B6	Sealing Materials Compaction Plant	Related to decommissioning of U/G	Cannot be decommissioned until shaft sealing is complete.
B7	Warehouse and Hazardous Mat'ls	Related to operation and decontamination	Will be decommissioned with Protected Area facilities.
B8	Air Compressor Building	Related to total project	Will be part of closure activity.
B9	Fuel Storage Tanks	Related to total project	Will be part of closure activity.
B10	Water Tanks	Related to total project	Will be part of closure activity.
B11	Water Treatment Plant	Related to total project	Will be part of closure activity.
B12	Pump House	Related to total project	Will be part of closure activity.
B13	Concrete Batch Plant	Related to decommissioning of U/G	Cannot be decommissioned until shaft sealing is complete.
B15	Service Water Settling Pond	Related to decommissioning of U/G	Cannot be decommissioned until shaft sealing is complete.
B16	Excavated Rock Stockpile (working)	Related to total project	Will be part of closure activity.
B17	Guard Houses	Related to total project	Will be part of closure activity.
B18	Storage Yard	Related to total project	Will be part of closure activity.
B19	Sewage Treatment Plant	Related to total project	Will be part of closure activity.
B20	ERMA Storm Pond	Related to total project	Will be part of closure activity.
B21	Helicopter Pad	Related to total project	Will be decommissioned at end of decommissioning period.
B22	Bus Shelters	Related to operation until start of D&C	Will be decommissioned at end of decommissioning period.
B23	Weigh Scale	Related to total project	Will be decommissioned at end of decommissioning period.
B24	Security Checkpoints	Related to total project	Will be part of closure activity.
B25	Security Monitoring	Related to total project	Will be part of closure activity.
B26	Stormwater Management Ponds	Related to total project	Will be part of closure activity.
B27	Parking Area	Related to total project	Will be part of closure activity.

Once the shafts have been sealed, the surface facility decommissioning will proceed generally in the following sequence:

- The UFPP, hoisting systems, and all other facilities in the (formerly) Protected Areas will be dismantled, removed, and sent off-site for disposal or recycling;
- Approval will be obtained to remove the Protected Areas' fencing and security systems, and they will also be subject to disposal or recycling;
- All surface facilities not required for the maintenance of site administration and staff-related purposes (the administration-focused systems) will be dismantled and removed (e.g., service water settling pond, hazardous material storage, etc.);
- At this point the site status will be an Administration Building supported by electrical utilities, water and sewage treatment, parking, and the perimeter fence; and
- Reconfiguration of the remaining administration facilities and utility services into a suitable package to support the postclosure period. The balance of site will be rehabilitated to greenfield conditions.

10.4.1 Decontamination

The issue of decontamination during decommissioning is expected to be of potential significance solely from the perspective of radiological matters. After placement operations are complete, operations staff will decontaminate the UFPP and other surface facilities except for fixed contamination in the concrete surfaces or equipment which will be addressed during decommissioning. It is expected that proper practices during the DGR's operational period will have effectively eliminated any residual concerns with other forms of hazardous materials.

The strategy adopted for decontamination, therefore, is based on the facility being free of loose surface contamination, with design elements intended to minimize the amount of fixed or exposure-based radioactive waste.

Although the radiological facilities will have been surveyed and loose contamination removed following the end of operations, the first step will be to re-survey and confirm the loose contamination-free status and the current exposure rate levels where fixed contamination or material sources exist. Following the removal, packaging and disposal of any contaminated material or removable equipment found (including any additional wastes generated in addressing concrete surfaces), the initial radiation survey would be repeated to confirm the absence of contamination.

The survey and clean-up activities will be carried out for all appropriate facilities including the underground facilities (if needed).

10.5 CLOSURE AND POSTCLOSURE

A minimized administration area will be maintained during the closure period in order to support the post-decommissioning monitoring systems. If at that time it is felt that permanent facilities are

no longer required, the monitoring systems could be supported by small enclosures for the electrical equipment, and all other remaining facilities would be removed, and the site essentially fully returned to its intended end-state.

The facility's environmental monitoring carried out during the operational and extended monitoring periods, as well as throughout the decommissioning stage will further be continued into the closure and postclosure periods. While the level of monitoring will be reduced, it is expected that the program will still address (at a minimum) groundwater and surface water quality issues, to ensure compliance with regulatory requirements.

In addition, safeguards containment / surveillance monitoring (e.g., an acoustic emissions or micro-seismic network) will be considered on the surface in the rock above and around the DGR to detect any noise that might be associated with an attempt to excavate into the repository. In all respects, inspections and containment / surveillance measures will continue for as long as necessary to ensure the full safeguarding of the sealed DGR.

As the closure period nears its end, the final approval to release the site for public surface use (with underground access excluded) will establish any final postclosure long-term monitoring needs. At that point, the monitoring would be finally configured, fenced and signed as required, and the site released in accordance with the obtained approvals.

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APPENDIX A: USED FUEL CONTAINER AND BUFFER BOX DESIGN

The used fuel container (UFC) and the bentonite buffer are the key components of the engineered barriers.

The role of the used fuel container (UFC) is to provide containment for used CANDU (CANada Deuterium Uranium) fuel and any other fuel deemed acceptable for the repository in accordance with the Nuclear Fuel Waste Act (S.C. 2002, c.23) and NWMO's waste acceptance criteria.

The role of the buffer is to:

- Inhibit microbiologically influenced corrosion;
- Fill the excavated volumes and support the surrounding rock;
- Inhibit flow and act as a sorption agent;
- Support the container; and
- Transfer heat to the surrounding rock.

The UFC uses standard available materials and can be packaged into Buffer Box bentonite assembly to:

- Facilitate construction and operations of the facility;
- Provide greater certainty of container placement state;
- Efficiently use raw materials (e.g., copper); and
- Improve system performance during the post closure evolution of the repository.

The UFC is designed to use readily available, pre-qualified ASTM/ASME pipe and plate (to form the hemi-spherical head) for the steel core. The corrosion barrier is a copper coating that is bonded directly to the external surface of the steel core. Copper coating eliminates creep performance concerns, avoids the need for micro-alloying, and requires significantly less copper than having a separate outer copper shell.

The relatively smaller and light-weighted used fuel container provides an opportunity to pre-pack the highly compacted bentonite around the UFC at surface. This eliminates the need to perform tight tolerance work in a radiological environment underground. Once packaged, used fuel container placement is completed by using specialized vehicles with modified handling attachments to place the container underground.

A.1 Design Requirements

Although there are many requirements, below are the primary design requirements that must be met. These apply to the container and the bentonite buffer.

A.1.1 Used Fuel Container

1. Material – The steel vessel materials shall meet the minimum strength and impact toughness requirements of the ASME Boiler and Pressure Vessel Code for the service conditions intended by the design. The materials shall be resistant to radiation-induced and hydrogen-induced embrittlement.
2. Container design – Container shall be designed to withstand the normal and accident loads during operation and handling and the loads in the repository. The pre-closure performance and post-closure performance of the container shall support the performance targets in the safety case.

Loads during operation and handling:

- a. Normal operation load – mechanical loads introduced during the normal operation and handling.
- b. Seismic loads – shaking load and the dynamic load associated with rock falls caused by earthquakes.
- c. Impact load – dynamic impact load associated with normal operations and handling accidents.
- d. Fire load – thermal load associated with a fire accident.

Loads in the repository include:

- a. Interglacial hydrostatic load – hydrostatic load that would be associated with a water column from repository depth to the surface of the repository site;
 - b. Glacial hydrostatic load – hydrostatic load that would be associated with a water column from repository depth to the surface of an icesheet of three kilometers in thickness covering the repository site;
 - c. Buffer swelling load – mechanical load exerted on the UFC by the expansion of the buffer material in the form of contact pressure. The magnitude and distribution of this load depends on the saturation level of the buffer material;
 - d. Seismic shaking load – dynamic load induced by earthquake in the repository;
 - e. Internal pressure – pressure caused by the gas trapped inside the UFC; and
 - f. Shear load – displacement load exerted on the UFC due to the relative movement of the surrounding rock along fracture lines. Such a load can be applied in a short duration, such as rock movement during an earthquake; it can also be slowly applied, such as rock movement due to long term geological evolution.
3. Leakage tightness – the container shall be leak-tight to maintain its function as containment.

4. Corrosion resistance – the materials, especially the corrosion barrier material, shall be resistant to corrosion in the DGR environment with a predictable corrosion rate. The following corrosion allowance shall be considered:
 - a. an allowance for corrosion attributable to all of the oxygen trapped in the repository;
 - b. an allowance for all of the chloride that may be present or flow through the repository;
 - c. an allowance for sulphide that might be present in the buffer and any sulphide produced by sulphate reducing bacteria;
 - d. an allowance for sulphide that might be present or produced in the rock that is capable of migrating to the container;
 - e. an allowance for microbially induced corrosion and/or corrosion events that combine trapped oxygen, water and radiation to damage the inside of the container; and
 - f. an allowance for flaw size detection limit.

A.1.2 Bentonite Buffer

1. Dry density – The dry density of the emplaced buffer shall be adequate to:
 - a. Suppress microbial growth – Microbes are suppressed at Water Activity < 0.96 which is achieved with the dry densities above; and
 - b. Provide interface contact pressure – The dry densities specified above generate a minimum of 100 kPa of interface contact pressure to ensure voids are filled in the room and to provide support to the container and excavated damage zone.
2. Heat Transfer – Bentonite geometry and container spacing shall be selected to sufficiently transfer heat to keep the container surface temperature below 100°C.

A.2 Used Fuel Container (UFC)

A.2.1 Used Fuel Container Description

The UFC is the main containment barrier in the engineered barrier system. Its primary safety function is to confine the radioactive material over a time frame in the order of 1 million years. This safety function would be fulfilled by:

1. Maintaining the UFC configuration and integrity against internal and external loads; and
2. Controlling the corrosion rate of the UFC materials so that containment can be maintained within the time frame of interest.

The UFC configuration and integrity will be maintained by a structural vessel designed to withstand loads. The corrosion rate will be controlled by applying a corrosion barrier outside the structural vessel.

The current reference UFC design, as shown in Figure A-1, includes a steel structural vessel made of mild carbon steel and a corrosion-resistant copper coating bonded to the exterior of the steel vessel. An internal steel structure referred as the Insert is designed to hold 48 used CANDU fuel bundles (i.e., configured in 4 layers with 12 bundles per layer). The UFC has an overall length of about 2.5 meters and a diameter of about 0.6 meter. The weight of a UFC loaded with used fuel bundles is about 3 metric tonnes.

The selection of the 48-bundle vessel is based on the results of the used fuel container sizing study which identified this design as an optimal mid-sized container in terms of vessel manufacturability and operation. This design permits the use of readily available standard materials to fabricate the structural vessel instead of a custom forged product. The size and weight of the container are manageable using commercially available equipment, and also better facilitate automated operations for fuel packaging, buffer assembly, handling and placement.

The reference UFC incorporate two hemi-spherical heads coupled with a standard steel pipe (referred as the “shell”) through welding. The hemi-spherical heads are designed for optimal stress distribution under external pressure. The weld is designed to provide sufficient strength while reducing the welding and inspection operations in the radioactive (hot cell) environment. The fully bonded copper coating is designed to achieve enhanced corrosion barrier strength and saving of material.

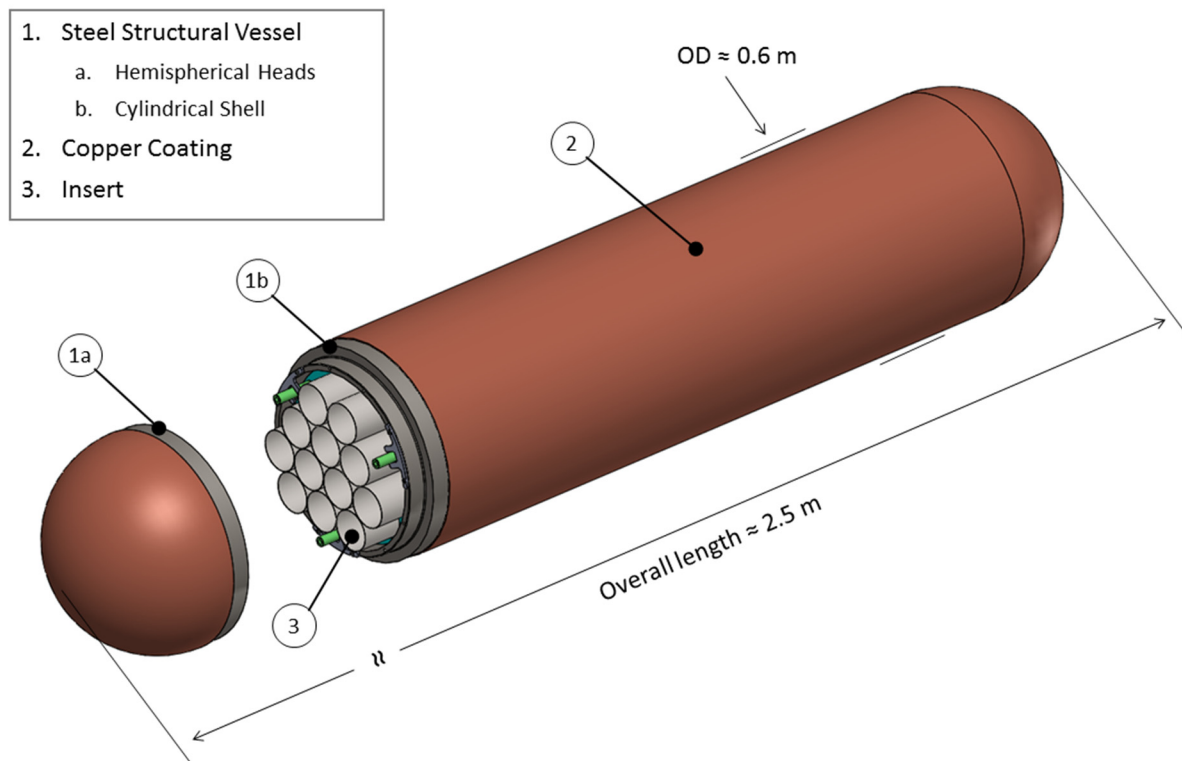


Figure A-1: The reference UFC design with a capacity of 48 bundles

A.2.2 Used Fuel Container Closure Weld

The used fuel container is sealed with a closure weld with a special weld joint design. In this design, a single path partial penetration weld of 8 mm to 10 mm in thickness is applied to the interface between the hemi-spherical head and the shell. An integral backing ring is designed to

hold the hemi-spherical head in place. This weld design is optimized for the compressive stress caused by the external pressure as the primary load in the repository.

NWMO has conducted feasibility evaluations of several welding technologies including Hybrid Laser Arc Weld process (HLAW) and Laser Preheated Gas Metal Arc Weld (LP-GMAW) processes, which can achieve high quality single path penetration for the UFC materials. The closure welding process is designed aiming fully automated operation or remotely controlled operation in a radioactive environment.

A.2.3 Copper Coating

Copper coating is selected as the design for the corrosion barrier of the UFC.

Copper is an excellent corrosion-resistant material, especially in an anoxic environment. Large scale research has been conducted on copper as a corrosion barrier material for nuclear waste disposal. It has been shown through accelerated experiments and conservative analyses that 1.3 mm of oxygen free pure copper would last more than 1 million years. The UFC copper coating is designed to be 3 mm as the minimum thickness.

The copper coating is applied in two product forms. The majority of the UFC surface that is away from the closure weld will be coated using an electrodeposition process prior to delivery to the Used Fuel Packaging Plant (UFPP). The closure zone (i.e., the narrow band adjacent to the closure weld location) will be coated using the cold spray process after the fuel is loaded and the hemi-spherical head is welded the shell in the UFPP.

For optimal corrosion performance, scratching, marking or attachment to the surface of the copper coating will be avoided to the maximum extent.

A.3 Buffer Box

Prior to transfer to the repository, the used fuel container is pre-packaged into a rectangular shaped buffer box. The Buffer Box (Figure A-2) is a 2-piece assembly made from highly compacted bentonite blocks with a machined cavity to house the used fuel container. The dimensions of the Buffer Box are approximately 1 m x 1 m x 2.9 m, and the loaded mass is approximately 8 tonnes.

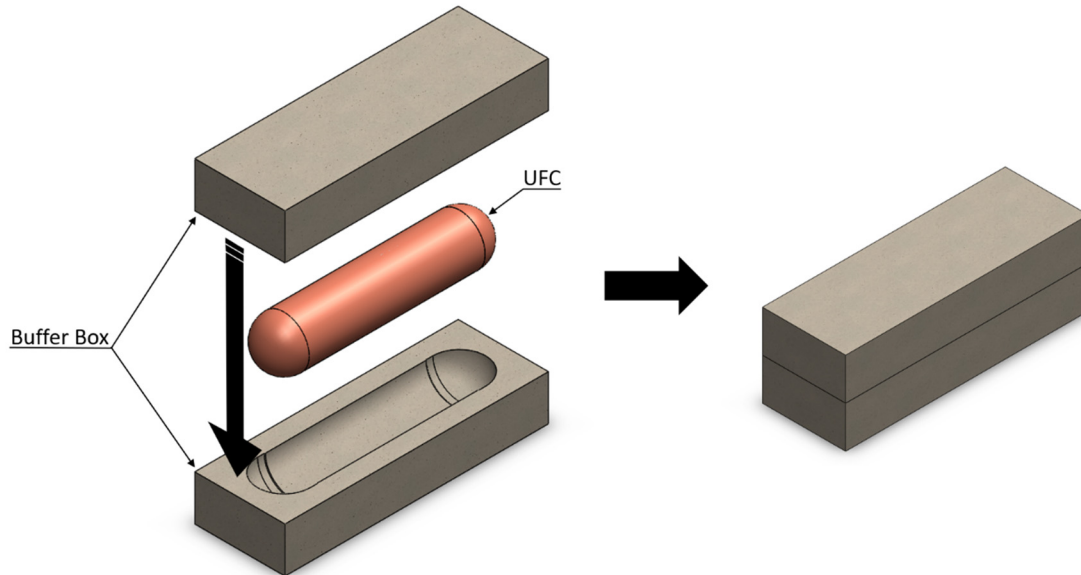


Figure A- 2: Used Fuel Container within Bentonite Buffer Box

The buffer box concept permits assembly of the highly compacted bentonite (HCB) to tight tolerances ensuring material voiding is minimized. The standard buffer box shape permits stacking and relatively simple placement within the placement room.

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