Design of the Long-term Waste Management Facility for Historic LLRW Port Hope Project – 13322

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ABSTRACT

The Municipality of Port Hope is located on the northern shores of Lake Ontario approximately 100 km east of Toronto, Ontario, Canada. Starting in the 1930s, radium and later uranium processing by Eldorado Gold Mines Limited (subsequently Eldorado Nuclear Limited) (Eldorado) at their refinery in Port Hope resulted in the generation of process residues and wastes that were disposed of indiscriminately throughout the Municipality until about the mid-1950s. These process residues contained radium (Ra-226), uranium, arsenic and other contaminants.

Between 1944 and 1988, Eldorado was a Federal Crown Corporation, and as such, the Canadian Federal Government has assumed responsibility for the clean-up and long-term management of the historic waste produced by Eldorado during this period.

The Port Hope Project involves the construction and development of a new long-term waste management facility (LTWMF), and the remediation and transfer of the historic wastes located within the Municipality of Port Hope to the new LTWMF. The new LTWMF will consist of an engineered above-ground containment mound designed to contain and isolate the wastes from the surrounding environment for the next several hundred years. The design of the engineered containment mound consists of a primary and secondary composite base liner system and composite final cover system, made up of both natural materials (e.g., compacted clay, granular materials) and synthetic materials (e.g., geosynthetic clay liner, geomembrane, geotextiles). The engineered containment mound will cover an area of approximately 13 hectares and will contain the estimated 1.2 million cubic metres of waste that will be generated from the remedial activities within Port Hope. The LTWMF will also include infrastructure and support facilities such as access roads, administrative offices, laboratory, equipment and personnel decontamination facilities, waste water treatment plant and other ancillary facilities.

Preliminary construction activities for the Port Hope LTWMF commenced in 2012 and are scheduled to continue over the next few years. The first cell of the engineered containment mound is scheduled to be constructed in 2015 with waste placement into the Port Hope LTWMF anticipated over the following seven year period.

INTRODUCTION

Port Hope is a town of just over 16,000 residents located approximately 100 km east of the city of Toronto in Ontario, Canada. The historic low-level radioactive waste (LLRW) and contaminated soil located at various sites around the community are the result of waste handling practices involving the refining of radium and uranium by a former Federal Crown Corporation, Eldorado Nuclear Limited. Waste placement occurred between the early 1930s and mid 1950s. These waste materials contain radium-226, uranium, arsenic and other contaminants resulting from the refining process.

Over the years, the waste has been managed and monitored by the Canadian Federal government and a final solution to LLRW waste management in Port Hope has been under development since the mid

1970s. A primary part of the activities to date is the monitoring and inspection of waste sites to ensure the waste does not pose a risk to human health or the environment.

The current Port Hope Area Initiative (PHAI) is a community-based program directed at the development and implementation of a safe, local long-term management solution for historic LLRW in Port Hope. It is the result of an agreement established in 2001 between the Government of Canada and the affected Municipalities of Port Hope and Clarington for safe cleanup, transportation, isolation and long-term management of LLRW. The PHAI includes two undertakings: i) the Port Hope Long-Term Low-Level Radioactive Waste Management Project (the Port Hope Project); and, ii) the Port Granby Long-Term Low-Level Radioactive Waste Management Project (the Port Granby Project located in the Municipality of Clarington). Only the Port Hope Project will be discussed herein.

The Port Hope Project consists of the construction and development of a Long-Term Waste Management Facility (LTWMF) and the remediation of contaminated sites in the Municipality of Port Hope with transfer of the contaminated material to the LTWMF. At the site of the LTWMF, the existing waste at the Welcome Waste Management Facility (WMF) will be remediated and included in the LTWMF. There are thirteen LLRW sites including the Port Hope Harbour and five industrial sites as well as numerous small-scale remediation sites still being identified through a survey of all properties within the Municipality. The total volume of waste material to be managed in the LTWMF is estimated at 1.2 million cubic metres. Remediation sites include former temporary storage sites, ravines, beaches, parks and vacant industrial sites all within the urban area of Port Hope. Combining to form the Port Hope Area Initiative Management Office (PHAI MO), Atomic Energy of Canada Limited (AECL) is the Project Proponent and Public Works and Government Services Canada (PWGSC) is managing the procurement of services. The MMM-CRA Joint Venture is providing detailed design, contract administration and construction inspection services for the Project.

History of LLRW in Port Hope Area

Beginning in 1933, industrial activities associated with radium refining, engaged in by Eldorado Gold Mines Limited (subsequently Eldorado Nuclear) (Eldorado), resulted in LLRW and marginally contaminated soil (MCS) accumulation in the Municipality of Port Hope. In the early years of refinery operations, the need to exercise care in management of process wastes was not recognized as it is today. Process residues and wastes were placed at various locations throughout the community and used as a source of fill material for construction and landscaping activities. In the 1940's the focus of ore processing shifted to uranium, and by 1948 Eldorado began placing waste at a designated site known as the Welcome WMF located in the Township of Hope, Ontario. Waste continued to be placed at the Welcome WMF until 1955. In 1988, Eldorado's assets were privatized by the Federal Government and ownership transferred to Cameco Corporation (Cameco). Cameco operated and maintained the Welcome WMF in accordance with the terms and conditions of the Canadian Nuclear Safety Commission (CNSC) license until 2010, when the Welcome WMF was transferred back to the Federal Government for the Port Hope Project.

PORT HOPE LTWMF DESIGN REQUIREMENTS AND OBJECTIVES

The Port Hope LTWMF will consist of an engineered, above-ground containment mound designed to contain and isolate the wastes from the surrounding environment for the next several hundred years. The LTWMF will also include infrastructure and support facilities such as access roads, administrative offices, laboratory, equipment and personnel decontamination facilities, waste water treatment plant and other ancillary facilities. An artist's rendition of the Port Hope LTWMF site with the completed engineered containment mound is presented in Figure 1.

Figure 1 - Artist's Rendition of Port Hope LTWMF Site

LTWMF Location

Through numerous studies and evaluations, the Welcome WMF and adjoining former Bailey's Auto Wreckers property was selected as the site of the new Port Hope LTWMF. Together, the Welcome WMF and former Bailey's property is approximately 50 hectares in size. The site is bounded to the north by Highway 401, to the west by Brand Road, to the east by Baulch Road, and to the south by private agricultural land.

The site has approximately 33 metres of relief in a southeast to northwest direction, with the existing buried waste mound of the Welcome WMF located in the southeast quadrant of the site. The northwest quadrant of the site is heavily treed except for an open area in the extreme northwest corner that contains a series of ponds that are part of the Welcome WMF's groundwater/surface water collection and treatment system.

Community Objectives

The community of Port Hope outlined a list of objectives through community based conceptual design reports. The reports detailed the community's objectives for site performance, site characteristics, and future site uses. The objectives were originally submitted as part of the then proposed Town of Port Hope and Hope Township WMFs, two independent WMFs that were being considered prior to the amalgamation of the Town and Township into the Municipality of Port Hope. The reports were compiled and utilized for the Port Hope Project since many of the objectives were common between the two reports. Some examples of the community-based objectives were:

1. Maintain LTWMF surface gamma radiation levels to within background levels
2. No fences that would delimit the extent or boundaries of the storage mound
3. Final shape of the mound to be irregular in shape and be compatible with local topography
4. Surface vegetation to consist of native species

The majority of the community based objectives revolved around future end uses of the site. The emphasis of the future use objectives was for the LTWMF to be used for passive recreation by the public following completion and closure of the LTWMF.

End Uses

As per the community based objectives, an aesthetically pleasing shape compatible with the local area and topography was identified as an objective for the engineered containment mound. However, the design of an irregular mound footprint as compared to a more efficient square or rectangular footprint would be more difficult to design and construct, and thus more costly. As such, it was decided that the footprint shape and final grades would be altered through the use of additional backfill over the final cover of the engineered containment mound to vary the final slopes to blend into the surrounding topography. In keeping with the end use objectives, the final design will also be required to accommodate surface features such as pathways, sports facilities, and plantings.

Design Life Goal

The design life goal for the engineered containment mound was established as several hundred years (e.g., 500 years). After final closure of the engineered containment mound, the Government of Canada, through AECL, will maintain control and responsibility for the LTWMF throughout the Maintenance and Monitoring Phase of the Project following closure.

Design Constraints and Assumptions

Design constraints and assumptions were developed as a part of the evaluation of alternatives process where various storage and management methods were analyzed and evaluated prior to the detailed design of the LTWMF. The following constraints and assumptions were determined to be applicable to the design of the LTWMF for the Port Hope Project:

1. Design life of several hundred years
2. Accept all LLRW and MCS waste from the remediation sites
3. Allow appropriate closure of the engineered containment mound for a wide range of final waste volumes
4. Minimize disturbance of existing forested areas on site
5. Construction of the engineered containment mound to occur in the summer season (i.e., phased design with construction over several summers)
6. Incorporate the existing on-site waste burial area as a part of the engineered containment mound footprint
7. Minimize double-handling of waste
8. Permit the placement of on-site and off-site waste simultaneously, but independently
9. Existing groundwater/surface water collection and treatment system will be upgraded for treatment of leachate and on-site generated wastewaters
10. New separate storm water management system for ‘clean’ surface water run-off

Capacity

The volume of waste that will be generated through remedial activities is estimated at 1.2 million cubic metres, but the actual volume will likely vary from this estimate. As a result, the engineered containment mound design required a high degree of flexibility to accommodate a wide range of potential actual waste volumes while still allowing appropriate final closure of the mound. Thus, the containment mound has been designed to accommodate actual final waste volumes ranging from approximately 0.76 million cubic metres to 2.36 million cubic metres. The range of waste volumes is achievable through varying the final waste grades, and final cover grade, from the perimeter to the central peak from a minimum of 5 percent slope (to promote surface water runoff) to a maximum of 25 percent slope (to minimize erosion).

ENGINEERED CONTAINMENT MOUND DESIGN

Engineered Containment Mound Phased Development

The engineered containment mound design involves a phased development consisting of four cells (Cells 1, 2A, 2B, and 3). A phased development was required to:

1. Minimize the amount of waste excavation required prior to establishment of the receiving cells (e.g., minimize the amount of temporary stockpiling that would result) as well as reduce temporary stockpiling of higher concentration wastes)
2. Accommodate seasonal constraints on cell base liner construction (i.e., construct through summer construction season)
3. Allow the cells to be developed in sequence and at the appropriate time in the overall Project schedule in order to be available to receive waste when required, but not before in order to minimize leachate generation

Cell 1 will be situated in an area of the site where limited contaminated material is present. As such, Cell 1 will be constructed first. Once Cell 1 is constructed, the on-site waste materials located within the footprint of Cell 2A will be excavated and relocated to Cell 1, followed by the construction of Cell 2A. Similarly, when Cell 2A construction is complete, the remaining waste materials within the footprint of Cell 2B will be excavated and relocated to Cell 1 and Cell 2A, followed by the construction of Cell 2B. Cell 3 will be for containment of co-mingled LLRW/soil/municipal refuse excavated from the Highland Drive Landfill and is scheduled to be constructed concurrently with Cell 2A. The individual cells have been designed primarily for base liner development only. Once all cells are constructed, Cells 1, 2A and 2B will function as a single common cell. Cell 3, which will contain the co-mingled LLRW/soil/municipal refuse, will remain as an isolated cell.

Service Life of Liner System Components

Achieving the design life goal of several hundred years for the engineered containment mound will be highly dependent on the service life of the engineered composite base and final cover system components. For the Port Hope Project, the use of synthetic and native materials that yield low hydraulic conductivities (i.e., 1 x 10^{-14} metres per second (m/s) for geomembranes, 1 x 10^{-9} m/s for compacted clay layers, 1 x 10^{-11} m/s to 5 x 10^{-11} m/s for geosynthetic clay liners) were used in the design.

The projected service life of geomemrbranes has been derived mainly from laboratory investigations involving accelerated aging tests. Based on laboratory testing, the service life for HDPE geomembranes is projected to be from several hundred to approaching 1000 years under certain conditions. Compacted clay layers, being comprised of natural soils, are considered to have unlimited service lives if protected from settlement, freeze/thaw, and/or desiccation.

Underdrain System

The excavation for the engineered containment mound will extend to a depth of up to 4 metres below the existing shallow groundwater table; therefore, a base underdrain system was incorporated into the design to maintain the shallow groundwater table below the base grades during base construction and initial waste placement. The base underdrain system will consist of a granular media drain that will be installed at the base perimeter of each cell and will drain the surrounding groundwater by gravity through a discharge pipe to the on-site groundwater/surface water collection and treatment system.

Double Composite Base Liner

A double composite liner system comprising natural and synthetic materials was designed for the base liner of the engineered containment mound. The depth of the excavation was selected to provide a net on-site clean soil balance as well as utilize the void created by the excavation of LLRW and MCS from the existing burial mound within the engineered containment mound footprint.

The double composite base liner design consists of, from top to bottom:

Upper Composite Liner

1. Geotextile fabric layer - 5 mm thick
2. Granular drainage layer (leachate collection layer) - 0.3 m thick
3. Geotextile fabric layer - 5 mm thick
4. Geomembrane liner - 80 mil (2 mm) thick HDPE
5. Geosynthetic clay liner - 5 mm thick

Lower Composite Liner

1. Geotextile fabric layer - 5 mm thick
2. Granular drainage layer (leak detection layer) - 0.3 m thick
3. Geotextile fabric layer - 5 mm thick
4. Geomembrane liner - 80 mil (2 mm) HDPE
5. Compacted clay layer - 0.75 m thick.

This will result in a total minimum base liner thickness of approximately 1.35 metres. The base liner system components are presented in Figure 2.

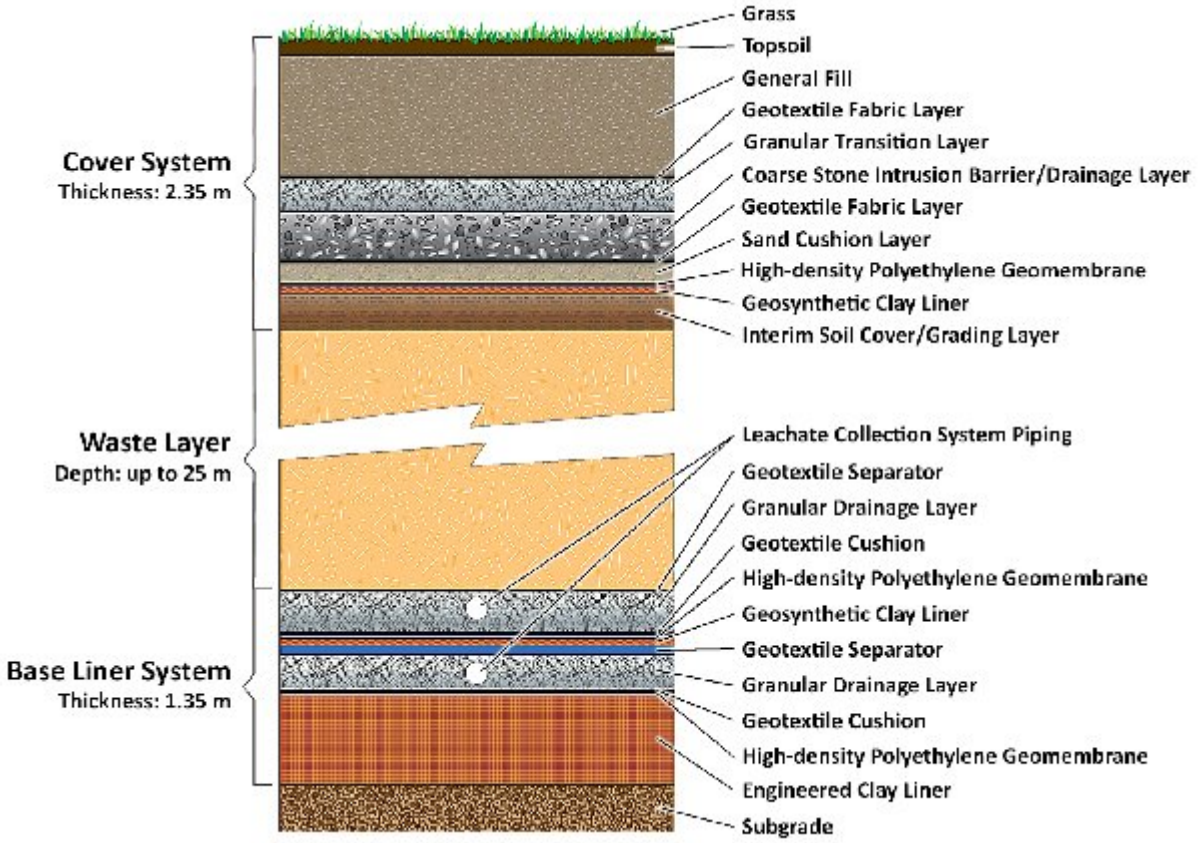

Figure 2 - Base Liner and Final Cover Systems

In order to protect the base liner system throughout the winter seasons through the period of phased base development, temporary protection along the edges of the individual cells being constructed is required. The temporary protection will consist of a number of measures that will include:

1. Overbuilding to provide sacrificial material at the edges of cells
2. Temporarily sealing the secondary liner to the primary liner to prevent water entry into the secondary collection layer
3. Installing a temporary perimeter berm and rain flap to contain leachate within the cell and prevent clean water from entering the cell
4. Placing additional soil to supplement the perimeter berm to provide further protection to the base liner components at the perimeter of the cell

Leachate Collection System

Within the primary and secondary drainage layers of the base liner system, a network of perforated HDPE collection pipes will be installed to facilitate leachate collection and monitoring. The piping will be installed in an east-west orientation with a lateral spacing of 30 metres. The perforated pipes will transition into non-perforated pipes and terminate in cleanout chambers located on the west and east perimeter of the containment mound, allowing both ends of the pipes to be accessed for future monitoring, cleaning and maintenance activities.

Final Cover

As with the base liner, the final cover system design comprises natural and synthetic materials. Prior to constructing the final cover system, a 0.3 metre thick interim soil cover/grading layer will be placed over the waste surface in Cells 1 and 2 to provide a smooth and clean working surface for subsequent final cover construction. In Cell 3, a gas collection and venting layer will serve as the interim soil cover/grading layer.

The engineered final cover design consists of, from top to bottom:

1. Vegetated topsoil layer – 0.15 m thick
2. General uncontaminated fill – minimum 1.0 m thick
3. Geotextile fabric layer – 5 mm thick
4. Fine stone layer – 0.2 m thick
5. Coarse stone intrusion barrier/drainage layer – 0.5 m thick
6. Geotextile fabric layer – 5 mm thick
7. Sand cushion layer – 0.2 m thick
8. Geomembrane liner – 80 mil (2 mm) thick high density polyethylene (HDPE)
9. Geosynthetic clay liner (GCL) – 5 mm thick
10. Interim soil cover/grading layer – 0.3 m thick

This will result in a total minimum final cover thickness of approximately 2.35 metres. The final cover system components are presented in Figure 2.

The purpose of the coarse stone intrusion barrier/drainage layer and the general uncontaminated fill layer are multi-faceted. The general fill layer fulfills several purposes including shielding of gamma radiation from the LLRW within the engineered containment mound, protection of underlying layers from freeze/thaw effects, additional storage capacity for precipitation infiltration, and to provide additional surcharge on the underlying geomembrane and GCL layers. The coarse stone intrusion barrier/drainage layer will prevent burrowing animals and/or root penetration from reaching the geomembrane, and will provide for lateral drainage of percolation from the overlying layers.

Landfill Gas Management

Certain waste to be placed in the engineered containment mound will contain organic materials (primarily co-mingled LLRW/municipal refuse from the Highland Drive Landfill) creating the potential to generate gases such as carbon dioxide and methane. While it is not anticipated that gas generation rates will be of sufficient quantity to require treatment to meet air quality criteria, the build-up of gases could cause a pressurisation of the base liner and final cover system, which could cause a premature failure of the composite liner systems. As such, a passive gas collection and venting system will be installed to relieve any gas pressure in a controlled manner.

The gas collection system will vent directly to the atmosphere (Cell 3) through a 300mm thick granular material layer placed over the waste immediately beneath the final cover. A network of perforated HDPE pipes within the granular layer and spread across the cell with 40 metre spacing will exit the cell envelope and vent to the atmosphere through vertical vents exiting through the final cover.

Due to the lower quantity of organics present in the material destined for Cells 1 and 2, the gas generation potential will be much lower than in Cell 3. The gas collection and venting system for Cells 1 and 2 will consist of sections of synthetic geocomposite installed directly beneath the final cover, which will vent to atmosphere through vertical vents exiting through the final cover.

INFRASTRUCTURE AND SUPPORT FACILITIES

A summary of the infrastructure and support facilities for the Port Hope LTWMF is provided as follows :

- Main Site Access Road – a 720 metre long dedicated access road will provide direct acess for construction vehicles to the site from Toronto Road. The main site access road was constructed in 2011.

- Perimeter Security Fencing – A security fence will be maintained around the entire perimeter of the LTWMF site to prevent unauthorized access during construction and development activities. The fencing will consist of 2 metre high, industrial chain link fence.

- On-site Access Roads – on-site access roads will consist of a series of one-way and two-way permanent and temporary roads to provide access to the various cells and on-site support facilities and for the transfer of on-site waste into the Cells.

- Administration, Visitor Centre, Laboratory and Maintenance Building – approximately 1,100 square metres of Gross Floor Area (GFA), the Administration building will house offices, visitors' spaces, meeting rooms, a laboratory for preparing samples for off-site analysis, and a garage area for site maintenance equipment. This building will be the only building to remain following the construction and development phase of the Project and is envisioned to continue to function as visitor centre into the future.

- Drive-Through Monitoring and Decontamination Building – approximately 550 square metres of garage space, this facility is where vehicles and equipment preparing to egress from the site will be monitored and decontaminated.

- Scalehouse and Security Building – at 10 and 50 square metres of GFA, the scalehouse and security building, respectively, will control vehicular access to and from the site. Vehicle weigh scales and radiation portal monitors at the site entrance/exit will record weight and radiation levels of each load of waste received at the LTWMF.

- Contractor Facilities - additional facilities to support the remedial contractor's operations on site will be provided by the Contractor and are likely to include equipment support facilities, field support facilities (e.g., locker room, lunchroom, personnel monitoring and decontamination facilities, first aid facilities, etc.), Contractor trailers, fueling station, etc.

- Wastewater Collection and Treatment System – during construction and development of the LTWMF, wastewater generated on site, include surface water run-off, groundwater, decontamination wash water, and leachate, etc., will be collected and conveyed to an upgraded collection pond system for treatment through a new on-site wastewater treatment plant. The new wastewater treatment system will be a chemical pre-treatment and clarification/reverse osmosis (RO)-based system with a treatment capacity of 1,090 cubic metres per day. A residuals management system consisting of vapour compression style evaporator and slurry drier equipment will dry the residuals stream to allow handling as a dry, solid waste. The new wastewater treatment plant is scheduled to be constructed between the fall of 2012 and the spring of 2014.

- Surface Water Management System - surface water run-off from the final cover of the engineered containment mound and from the remaining areas of the LTWMF site following closure of the containment mound will be conveyed by surface ditching to a new storm water management pond to be located in the southwest corner of the site. The new storm water management pond will outlet to a tributary to Brand Creek via road side ditches along Brand Road.

An artist's rendition of the decontamination building, facility operations centre (administration building), and the weighing station is presented in Figure 3.

Figure 3 - Artist's Rendition of LTWMF Support Facilities

PROJECT SCHEDULE

Preliminary construction activities for the Port Hope LTWMF commenced in 2012 and are scheduled to continue over the next few years. The first cell of the engineered containment mound is scheduled to be constructed in 2015 with waste placement into the Port Hope LTWMF anticipated over the following seven year period.