OPG's DEEP GEOLOGIC

REPOSITORY

FOR LOW & INTERMEDIATE LEVEL WASTE

Cost and Risk Estimate for Packaging and Transporting Waste to Alternate Locations

December 2016

Prepared by: Energy Solutions Canada

OPG CD# 00216-REP-03450-00001-R000

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Document History

Title:	Cost and Risk Estimate for Packaging and Transporting Waste to Alternate Locations		
Report Number:	00216-REP-03450-00001		
Revision:	R000	**Date:**	December 2016
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Executive Summary

This study describes and documents the estimate developed by Energy*Solutions* Canada to determine the incremental cost to:

1. Package the entire inventory of radioactive waste (excluding used fuel) with an estimated total volume of about 150,000 cubic meters that is expected to reside at Ontario Power Generation's (OPG's) Western Waste Management Facility (WWMF) for transportation, and
2. To transport these waste packages on public roads from the WWMF to an alternate Low and Intermediate Level Waste (L&ILW) Deep Geologic Repository (DGR) that is not located on the Bruce Nuclear site.

The inventory of low level waste (LLW) and intermediate level waste (ILW) that forms the basis for the estimate provided in this study includes that generated by the operation of the Pickering, Darlington and Bruce nuclear plants that is anticipated to reside at the WWMF at the time that the L&ILW DGR is expected to be available to initiate waste emplacements. For purposes of this study, cost estimates are developed for a range of road transport distances for two scenarios, including 100 km and 300 km with DGR availability beginning in year 2045 at an alternate location with a host geology of sedimentary rock, and 200 km and 2,000 km with DGR availability beginning in year 2055 at an alternate location with a host geology of crystalline rock.

The information in this study has been developed to facilitate OPG's response to the Federal Minister of Environment and Climate Change request for additional studies and information before a decision could be made to approve the Environmental Assessment for the DGR Project, which is proposed to be located on the Bruce Nuclear site. The body of work described in this study focuses on the activities, costs and risks that are incremental to those of the retrieval plan. In this regard, the costs included in this estimate are limited to the incremental costs for packaging the WWMF waste for transportation, road transport of these packages from the WWMF to an alternate location, and the handling and off-loading of such transport packages at the alternate location. Similarly, the associated assessment of risks is limited to incremental radiological and conventional risks. These incremental activities, costs and risks would otherwise be avoided if the L&ILW DGR is located on the Bruce Nuclear site.

The cost estimates provided in this study are considered Class 5 estimates per the classification system and guidelines published by AACE International, an industry recognized organization for promoting standards for the development of such project cost estimates. Class 5 estimates are typically developed for projects such as this that are in the early conceptual stage to provide a high-level indication of the approximate cost for a project. Consistent with Class 5 estimating practices, a higher level top-down, lump-sum, aggregate unit rate costing methodology is used based on similar past projects, operational experience, knowledge of requirements and the associated level of effort needed to complete such projects.

For purposes of this study, indicative costs estimates are developed for each of the 12 waste categories, (including 4 LLW and 8 ILW), for each assumed transport distance, (including 100 and 300 km for the 2045 scenario, and 200 and 2,000 km for the 2055 scenario). These waste categories are used to generalize and assimilate the common characteristics of the associated

bulk waste, selecting waste container types that are representative of the entire inventory, and identifying typical large component preparation processes, for the purpose of simplifying the cost estimating methodology. Numerous assumptions and judgments are made for each waste category based on experience. At the waste category level, the estimate includes the cost for supply of transport packagings, supply of waste category-specific equipment, and providing truck transport services for the respective waste category.

Adjustment factors which increase with transport distance are applied to the resulting total estimated cost for each waste category to account for the associated technical uncertainties and operational risks. Technical uncertainties include variability in the actual waste characteristics, waste container types, and large component preparations to render them transportable. Operational risks include potential interruptions and delays in waste retrieval and packaging operations, and truck transports and turnaround times given that specific logistical planning based on site and route selection has not been performed. All of these factors affect the assumed transport packaging approaches, transport packaging and tractor/trailer fleet sizes, and trucking costs that are not discretely evaluated and accounted for given the conceptual nature of this study.

Wherever possible, the transport packagings chosen for each waste category are based on currently existing standard designs that can be procured from commercial sources. For unique waste categories where such standard transport packagings are not suitable or compatible, the design and procurement of custom waste category-specific packagings are assumed. Both reusable transport packagings, (i.e., overpacks for waste containers that can be removed and reused for multiple shipments), and one-time transport packagings (i.e., those that contain the bulk waste itself and that are used for one shipment to avoid waste rehandling), are used depending on waste category-specific requirements.

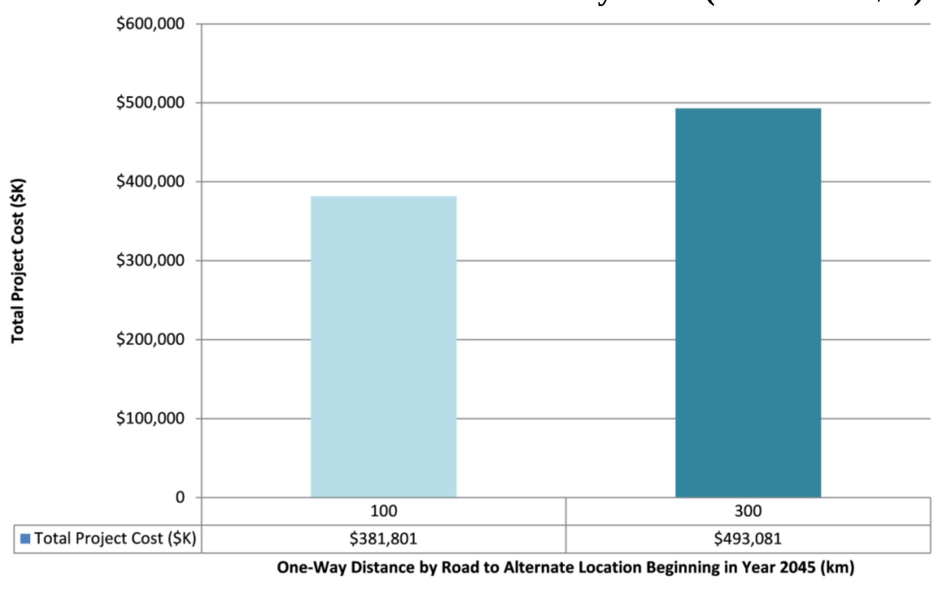
Given the future timeframe when such transports would occur, it is assumed that a sufficient number of new, (rather than existing), transport packagings of each type are procured to facilitate waste packaging for transport in accordance with the Canadian Nuclear Safety Commission (CNSC) regulations that govern the transportation of radioactive materials. The quantities of such packagings needed to support daily shipping rates that keep pace with the planned activities at the Bruce Nuclear site for waste retrieval operations from the WWMF are determined, which increase with transport distance and reusable packaging turnaround time. In total, it is estimated that 1,200+ transport packagings of 14 different types are needed, of which about 40% are custom designs and 20% are reusable.

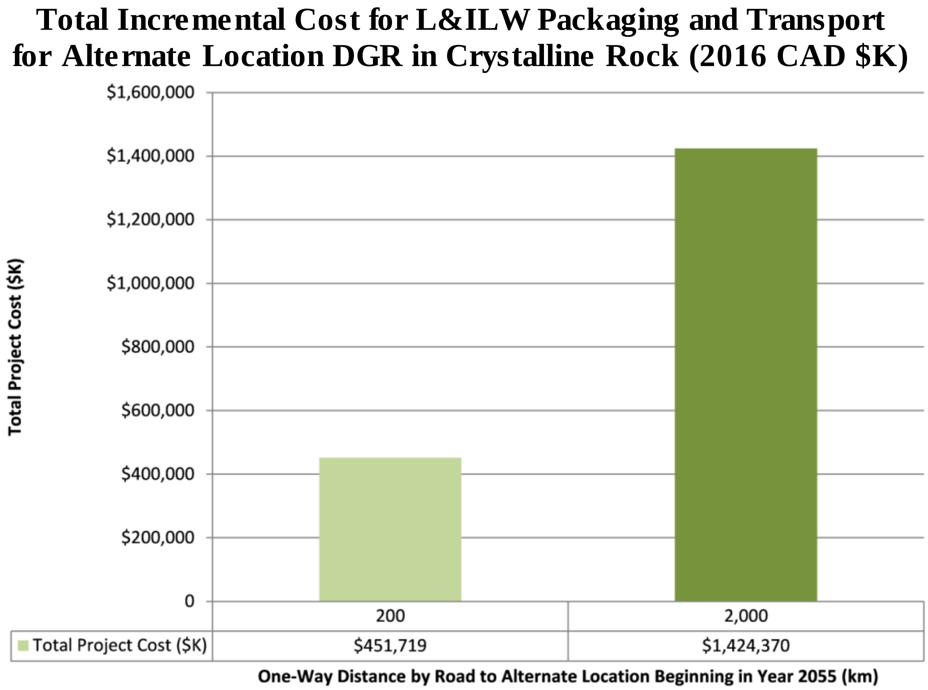
In general, the existing or planned infrastructure, facilities and resources at the WWMF and alternate location that are already allocated to perform baseline activities at these sites are not sufficient to perform the incremental activities necessary for transport operations to an alternate location. As such, estimates for the associated incremental equipment and labour resources needed to conduct transport packaging and road transport preparation operations at the WWMF, and transport packaging off-loading operations on the alternate location are included. The equipment to support such site operations includes both common heavy industrial equipment and specialized equipment, some of which would need to be custom designed and purpose-built. To perform such site operations, it is estimated that an incremental dedicated staff of about 21 full-time equivalents split between both sites for the estimated 30+ year duration of the project would be needed for transport operations to keep pace with the planned activities at the Bruce Nuclear site for WWMF waste retrieval operations.

Truck transport services are assumed to be procured from Canadian based commercial service providers. Tractor/trailer types that are suitable for the respective load are utilized. To the maximum extent achievable, the waste categories, transport packagings and tractor/trailer types are selected and configured to be compliant with the Ministry of Transportation, Ontario (MTO) limits for compliant legal size and legal weight road transports not requiring a permit to minimize time of transit restrictions. In cases where the load exceeds these limits, permitted oversized and/or overweight road transports are assumed, with the commensurate time of transit restrictions. In total, depending on distance, it is estimated that a fleet of 40 to over 275 tractor/trailers of different types traveling a total of 2,300,000 to nearly 48,000,000 kilometers and consuming approximately 220,000 to 4,600,000 liters of diesel fuel are needed to complete road transportation operations over the 30+ year period. Of the total number of shipments, approximately 11% are estimated to be oversized and/or overweight.

To derive the indicative total incremental project cost for each of the assumed road transport distances for the two scenarios, the associated waste category-specific estimates for packaging and transport are summed, and the other costs that are common to all waste categories are added. These include the costs for the supply of site equipment that is common to all waste categories, labour performed on the respective sites to facilitate transport operations, consumable materials, and periodic equipment maintenance and refurbishment. Consistent with Class 5 estimating practices, a prudent management reserve is included in the total estimated cost for the project to provide an allowance for the project-level unknowns at this juncture, given the future timeframe, long duration and the early conceptual stage of this project. The resulting indicative total project cost for packaging and transporting the entire inventory of L&ILW from the WWMF and off-loading them at the alternate location for the assumed 100 km and 300 km distances for a sedimentary rock DGR with an availability in year 2045, and the 200 km and 2,000 km distances for a crystalline rock DGR with an availability in year 2055 are shown below.

Total Incremental Cost for L&ILW Packaging and Transport for Alternate Location DGR in Sedimentary Rock (2016 CAD $K)





In all it is estimated that more than 22,000 total shipments on public roads over a 30+ year period are needed to package and transport the entire inventory of L&ILW from the WWMF to an alternate location. Of the total volume of L&ILW that would be transported to the alternate location, 93% is LLW and only 7% is ILW. Similarly, of the total number of shipments of L&ILW to the alternate location, 67% are LLW shipments and 33% are ILW shipments.

This study also provides a preliminary assessment of the incremental risks associated with the packaging and road transport of the L&ILW from the WWMF and off-loading them at alternate location. Both the incremental radiological and conventional risks are assessed, including the risk of exposure to ionizing radiation during normal and hypothetical accident conditions, and the conventional risks to health, safety and the environment for such transports. The assessment concludes that the associated incremental risks are limited and bounded. They are judged to be determinate and quantifiable in terms of their probability of occurrence and their potential consequences. Further, it is judged that the profile of incremental risks can be effectively managed and mitigated without undue risk to the public. The preliminary assessment of incremental risks is underpinned by data derived from 40+ years of safe radioactive material transports worldwide, and historical data for the transport of commercial cargo using heavy trucks on public roads.

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List of Acronyms

AACE....Association for the Advancement of Cost Engineering
CAD....Canadian Dollar
CNSC....Canadian Nuclear Safety Commission
CT....Calandria Tube
CTI....Calandria Tube Insert
DGR....Deep Geologic Repository
D-RWC....Darlington Retube Waste Container
EF....End Fitting
ETH....Encapsulated Tile Hole
HX....Heat Exchanger
ILW....Intermediate Level Waste
IP-2....Industrial Packaging, Type 2
L&ILW....Low and Intermediate Level Waste
LLSB....Low Level Waste Storage Building
LLW....Low Level Waste
LSA....Low Specific Activity
MSC....Modular Shielded Container
MTO....Ministry of Transportation, Ontario
ODC....Other Direct Costs
OPEX....Operational Experience
OPG....Ontario Power Generation
PT....Pressure Tube
PTNSR....Packaging and Transport of Nuclear Substances Regulations
RL....Resin Liner
RWC....Retube Waste Container
SCO....Surface Contaminated Object
SG....Steam Generator
TD....Technical Document
THEL....Tile Hole Equivalent Liner
THL....Tile Hole Liner
USD....United States Dollar
VAT....Value Added Tax
WWMF....Western Waste Management Facility

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1. Introduction and Purpose

Ontario Power Generation Inc. (OPG) is currently seeking a licence to prepare the site and construct a Deep Geologic Repository (DGR) for its low and intermediate level radioactive waste (L&ILW) at the Bruce Nuclear site in the Municipality of Kincardine (the DGR Project at the Bruce Nuclear site).

In 2015 a Joint Review Panel (Panel) issued the Environmental Assessment Report on the DGR Project at the Bruce Nuclear site, which concluded that provided certain mitigation measures were implemented *"the project is not likely to cause significant adverse environmental effects"*. The Panel also concluded that *"the DGR is the preferred solution for the management of L&ILW"* and *"the sooner the waste is isolated from the surface environment the better."*

In February 2016 the federal Minister of Environment and Climate Change requested that OPG provide additional information prior to making a decision on the environmental assessment (EA) of the DGR Project at the Bruce Nuclear site. In particular the Minister requested:

"A study that details the environmental effects of technically and economically feasible alternate locations for the Project, with specific reference to actual locations that would meet OPG's criteria for technical and economic feasibility. In conducting this study, OPG is to detail the thresholds for what is considered to be technically and economically feasible. In addition, OPG is to indicate what the incremental costs and risks would be for additional off-site transportation of the nuclear waste."

In response to OPG's letter dated April 15, 2016 describing OPG's proposed approach to responding to the Minister request, the Canadian Environmental Assessment Agency (Agency) provided clarification as follows:

"[OPG] has indicated that it intends to provide an assessment of the environmental effects of two technically and economically feasible geologic regions in Ontario, specifically in a sedimentary rock formation in southern Ontario and in a granite rock formation located in central to northern Ontario, without providing specific reference to actual locations. …

…. the Agency requests that the analysis of the environmental effects of the alternate locations to be provided by OPG provide a narrative assessment that does not assume that alternate sites in the geologic formation would have the same geographical and hydrological characteristics of the preferred site."

The response to the information requested is documented in four reports, a main submission and three Technical Documents (TDs). The main submission provides context, describes the project for study purposes, summarizes the studies, and presents the overall findings. The technical documents, of which this is one, present detailed information on different elements of the information requested. The technical documents are:

- Description of Alternate Locations
- Environmental Effects of Alternate Locations
- Cost and Risk Estimate for Packaging and Transporting Waste to Alternate Locations

The technical documents and the main submission rely to some degree, on content in the others. Cross-references are provided where appropriate. These four documents in total constitute the response to the Minister on this particular study request.

1.1 Focus of This Technical Document

This report provides an indicative estimate of the incremental cost and the associated risks to:

- Package the entire inventory of L&ILW, including waste containers, large components and repackaged bulk waste, that are projected to reside at OPG's Western Waste Management Facility (WWMF) by years 2045 and 2055 so that they are suitable for transportation,
- Transport the packages by truck on public roads to the alternate location, and
- Off-load the transport packages at the alternate location.

This TD is specific to the off-site transportation component of the Minister's request. The body of work described in this study focuses on the activities, costs and risks that are incremental to the planned activities at the Bruce Nuclear site.

The estimate described in this study includes the cost for the following major work activities directly associated with the transportation of the inventory of L&ILW from the WWMF to an alternate location:

1. *At WWMF:* The cost to supply the necessary transport packagings[1] for the waste containers, large components, and repackaged bulk waste where necessary, and to supply and install the associated equipment needed to facilitate transport packaging operations at the WWMF. The cost for performing the operations needed to install the transport packagings to render these waste forms transportable from the WWMF. The cost to supply the devices to secure the packages to the truck transport conveyances and to perform the operations needed to place and secure the transport packages on the conveyances.
2. *On Public Roads:* The cost to provide the tractor/trailer equipment and trucking services needed to transport the packages on public roads from the WWMF to the alternate location.
3. *At Alternate Location:* The cost to supply and install the equipment needed to facilitate transport package off-loading and/or handling at the alternate location. The cost to perform the operations needed to remove these waste form contents (i.e., waste containers, large components or repackaged bulk waste), from their transport packagings (if the packagings are to be reused); or to handle the transport packagings with their waste form contents intact (if the packagings are not to be reused to avoid waste rehandling), for subsequent disposition.
4. *On Public Roads:* The cost for return transport of the truck conveyances and the empty reusable transport packagings to the WWMF.

[1] In many cases the term "packaging" rather than "package" is used throughout this report to be consistent with the terminology defined in the IAEA SSR-6 transportation regulations. In this context, packaging means the physical barrier that envelops, confines, contains and shields the waste whereas package means the combination of the transportation packaging and the waste itself.

The cycle is repeated until the entire inventory of L&ILW projected to reside at the WWMF is transported to and resides at the alternate location. Cost estimates are developed for each of the assumed road transport distances for both the year 2045 and 2055 DGR availability scenarios at a daily shipment rate that keeps pace with the planned activities at the Bruce Nuclear site for waste retrieval operations from the WWMF.

This study focuses on incremental activities necessary for transport packaging, road transportation and off-loading described above. The respective costs are incremental to the planned activities at the Bruce Nuclear site that would otherwise be avoided if the L&ILW DGR were located on the Bruce Nuclear site (and thus not requiring transport on public roads). The differentiation of the DGR Project at the Bruce Nuclear site and incremental activities and the associated costs for the alternate location are shown in Figure 1-1.

For purposes of this study, the complete inventory of L&ILW at the WWMF to be packaged and transported is grouped into waste categories, as described in Section 2, to facilitate and simplify the associated cost estimating methodology. These include four LLW waste categories with an estimated total volume of 139,000 to 147,000 m^3, and eight ILW waste categories with an estimated total volume of 10,000 to 11,000 m^3. As defined in Section 2, this L&ILW inventory includes the operational and refurbishment L&ILW generated by OPG's nuclear generating station reactors at the Pickering, Darlington and Bruce Nuclear sites until the time that the L&ILW DGR is available to initiate emplacements, i.e., years 204 and 2055.

For the sole purpose of developing the subject incremental cost estimate, a range of road transport distances are assumed to cover the two alternate location scenarios. The first is assumed to be located at a distance of 100 km to 300 km (by road) from the WWMF. This alternate location is assumed to have a host geology of sedimentary rock and to be available for waste emplacement beginning in year 2045. The second is assumed to be located at a distance of 200 km and 2,000 km (by road) from the WWMF. This alternate location is assumed to have a host geology of crystalline rock and to be available for waste emplacement beginning in year 2055. All truck transport operations on public roads are assumed to be performed in compliance with the Ministry of Transportation, Ontario (MTO) truck transport regulations.[2]

For purposes of developing the subject cost estimate, Energy*Solutions* (ES) has applied its extensive experience as the largest waste management and transporter of radioactive materials in North America for the past 40 years. This infrastructure includes a licenced waste processing, interim storage and transportation facility in Brampton Ontario. ES owns and operates an extensive fleet of transport equipment and vehicles through its subsidiary Hittman Transportation Services to service its commercial customers and to support its own nuclear waste management processing and disposal facilities. ES is also a major production manufacturer and supplier of waste packaging and transport container systems through its subsidiary MHF Services. This includes freight container overpacks that are suitable for road transport such as those pictured in Section 2.3 of this report. As a result, ES has an extensive fleet of waste packagings that are suitable for transport with known capabilities and costs. ES has used the associated operational experience (OPEX) and historical cost data to develop the subject AACE International[3] Class 5

[2] Ministry of Transportation Ontario, Highway Traffic Act, Ontario Regulation 413/05, "Vehicle Weights and Dimensions – for Safe, Productive and Infrastructure Friendly Vehicles," November 29, 2016.

[3] The Association for the Advancement of Cost Engineering is currently doing business as AACE International.

indicative cost estimate to supply, package and transport the entire inventory of L&ILW from the WWMF to an alternate location for the assumed road transport distances and off-loading them based on our process knowledge, past projects and judgment; (rather than more detailed task-based line-item estimating and scheduling). Beyond the subject study, no commitments to ES or any other supplier for such waste packagings and transport services has been made.

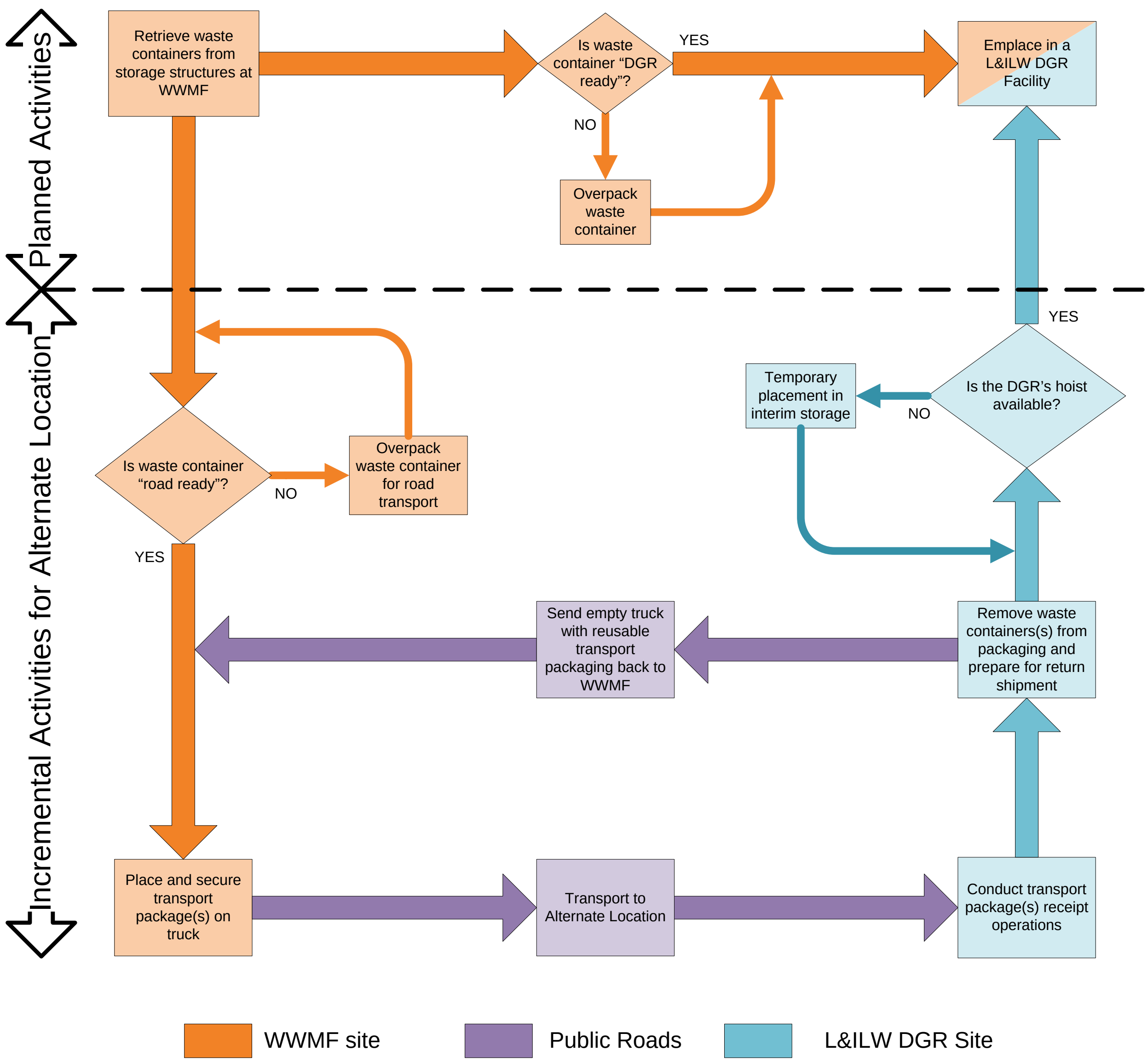

Figure 1-1: Differentiation of Planned and Incremental Activities and Costs for Alternate Location

For the purpose of this study, a preliminary assessment of risks is performed that includes the incremental radiological and conventional risks to package, transport and off-load the entire inventory of L&ILW from the WWMF to the alternate location. The radiological risk assessment described in Section 2 is primarily based on supporting information and data published by international nuclear industry organizations. Similarly, the assessment of conventional risks described in Section 2 is based on information and data from transportation agencies. The associated risks to members of the public and crew members are assessed for normal conditions of transport and hypothetical transport accident conditions.

1.2 Basic Framework

OPG has previously developed a plan for retrieval of the L&ILW in interim storage at the WWMF to prepare it for emplacement in the DGR at the Bruce Nuclear site. The plan includes the identification, estimated quantities, and sequence for retrieval of the bulk waste, waste containers and large components for processing and packaging them in a manner that renders them ready for emplacement in the DGR at the Bruce Nuclear site over a 30+ year period. This plan is referred to as the planned activities at the Bruce Nuclear site throughout this document.

Since the DGR is proposed to be located on the Bruce Nuclear site which includes the WWMF, the plan did not contemplate packaging the waste in a manner that is suitable for transportation off-site and transporting it on public roads to an alternate location. As described in Section 2, waste packaging standards and regulations for transportation of L&ILW on public roads are substantially more robust and demanding than those for interim storage and/or repository emplacement within an owner-controlled licenced nuclear facility. For purposes of this estimate, the associated incremental cost for transport packagings and equipment supply, and the cost for the labour, materials and services needed to perform the handling, transportation packaging, road transportation and off-loading operations are determined.

The assumed sequence for packaging and transporting each category of L&ILW from the WWMF to the alternate location and off-loading them follow the general order and time intervals developed for the planned L&ILW retrieval plan. The specific calendar years in the plan are normalized and the respective general sequence and time intervals are established for the purpose of determining the basic parameters used in the estimate, e.g., the rate of daily shipments required. The resulting sequence and time intervals for each waste category are as shown in Table 1-1.

Table 1-1: Waste Retrieval Sequence and Time Intervals

Waste Category	Retrieval Year (normalized)
Low Level Waste Categories	
Low Level Waste Storage Building (LLSB) Waste Containers (DGR-ready & Other)	1 to 26
Bruce Steam Generators (segments)	3 and 4
Trench Waste	6 to 8
Heat Exchangers (intact & segments)	9
Intermediate Level Waste Categories	
IC-2 Tile Hole Fixed Liner Waste	2
IC-2 Tile Hole Removable Liner Waste	3
Quadricell Resin Liners	4
IC-12/IC-18 Resin Liners	10
IC-18 Tile Hole Equivalent Liner Waste	4 to 10
IC-2 Grouted Tile Holes	12
Bruce Retube Waste Containers (RWCs) (Units 1 & 2 and future Units 3-8)	30 and 32 to 33
Darlington RWCs (Units 1-4)	31 and 32

1.3 Planning Assumptions for Cost Estimating

For the purpose of developing the indicative cost estimate described in this study, the following basic planning assumptions are made:

1. The inventory of LLW and ILW that must be packaged for transportation and transported on public roads includes that which resides at the WWMF and that which is generated by plant operations at the time that the DGR at an alternate location would be available to initiate waste emplacements. For purposes of this study, this is assumed to be 2045 or 2055 depending on the host geology of the DGR at the alternate location and the associated transport distance as described in Section 1.1.
2. The available inventory data for the WWMF waste categories is used, including quantities, physical and radiological properties. For some waste categories, specific data within a waste category is not differentiated, i.e., all bulk waste forms, waste container types, large component families within a waste category are treated the same. As described in Section 2, waste container types that are representative of an entire WWMF waste category inventory are chosen for the purpose of determining transport packaging types and quantities.
3. All shipments are assumed to be made by truck transport on public roads[4]. For purposes of this study, cost estimates are developed for two alternate location scenarios with two road

[4] Experience has shown that for large long duration transport campaigns such as this, transport of nuclear waste by rail would require dedicated trains, rail siding construction on both sites to facilitate direct rail access and staging of multiple railcars, and potential upgrades to secondary railroads (if mainline rail routes are not available). Alternatively, intermodal trucking between the nearest viable railhead to both sites would be required.

transport distances each, including 100 km and 300 km for a DGR in sedimentary rock with an availability beginning in year 2045, and 200 km and 2,000 km for a DGR in crystalline rock with an availability beginning in year 2055. No routings for these assumed road transport distances are identified or assumed.

4. Specific transport planning, including route selection, and logistical planning and scheduling have not been developed for purposes this study. Numerous assumptions and judgments are made throughout this study based on available inputs and industry OPEX to accomplish the objectives of this study to develop the respective indicative cost estimate and to assess risks. These assumptions and judgments likely introduce uncertainties into the cost estimate results, e.g., variability in the type and quantity of transport packagings needed and truck transport cycle times. For purposes of this estimate, cost adjustment factors are used for each waste category to account for such uncertainties.

5. A preference is given to maintaining the size and weight of road transports within the MTO limits for compliant truck shipments not requiring a permit. These fully compliant shipments are essentially assumed to be unencumbered other than normal traffic patterns and truck transit 24 hours per day is assumed. However, for several waste categories oversized and/or overweight road transports requiring permitting are necessary. For such shipments, both provincial and local permitting from all municipalities along the route having jurisdiction would be necessary, which would likely impose movement restrictions, e.g., local routing, seasonal and time of day limitations. It is assumed that the resulting combination of restrictions imposed by such permits would limit truck transits to an average of 8 hours per day for such shipments. For purposes of this estimate, shipments that exceed the MTO size restrictions of 23 m long, 2.6 m wide and 4.15 m high; and/or weight restriction of 93,000 lbs. (42.2 tonne) for the combined truck conveyance and transport package are assumed to be permitted.

6. Consistent with the regulatory requirements for transportation, the packaging specifications and type depend on the radiological characteristics of the waste being transported, including the unshielded surface dose and the isotopic content of the waste, as described in Section 2. For purposes of identifying the transportation packaging type for each waste category, it is assumed that the majority of LLW requires at least a Type IP-2 industrial packaging with the balance of LLW requiring Type A packaging (which is a more robust packaging specification). Similarly, the majority of ILW is assumed to require a Type B packaging (which is the most robust packaging specification) with the balance of ILW requiring a Type A packaging. The later assumption is based on a high level review of available radiological data for some CANDU reactor fuel channel waste which is assumed to be representative of all ILW. For purposes of this estimate, cost adjustment factors are used for each waste category to account for such radiological and packaging uncertainties.

7. Existing commercially available transport packaging designs are utilized where compatible and compliant for a particular waste category consistent with the regulatory requirements governing transportation, as described in Section 2. The estimated cost for supply of such packagings for existing designs is based on OPEX. For waste categories where no suitable transport packaging currently exists in industry, the design and Canadian Nuclear Safety Commission (CNSC) licencing (in the case of Type B packagings) of new custom transportation packagings is assumed and estimated. The cost for supply of such packagings

for new designs is estimated based on comparisons to similar packagings and adjusted accordingly. Given the number of dedicated transport packagings needed for such a large campaign, and that the timeline for initiating such transports would not begin until at least 2045, it is assumed that all new transport packagings are purchased in sufficient quantities to facilitate the needed daily shipping rate, transport distances and turnaround time. For waste streams that utilize an existing packaging design, transport packagings from the existing fleet are not used since it is assumed that they will be functionally obsolete in this timeframe and beyond their service life per transport regulations.

8. The sequence and time intervals for transporting waste in each category from the WWMF to an alternate location is assumed to align with the planned activities at the Bruce Nuclear site described in Section 1.2. The same sequence and time intervals are assumed for the 100 km and 300 km year 2045 scenario, and the 200 km and 2,000 km year 2055 scenario described in Item 3 above. The number of reusable transport packagings, package-specific equipment sets and tractor/trailer sets required is increased as a function of distance to maintain the same shipping rates and transport campaign durations across all cases.

9. The existing or planned infrastructure, facilities and resources for the DGR at the Bruce Nuclear site that are already allocated to perform baseline activities do not have sufficient reserve capacity to perform the incremental activities necessary to facilitate transportation to an alternate location. As such, estimates for the associated incremental equipment and labour resources needed to conduct transport packaging and preparation for road transport operations at the WWMF, and transport packaging off-loading operations at the alternate location are included. To perform such site operations, it is assumed that an incremental dedicated staff at both locations for the estimated 30+ year duration of the project are needed to align transport operations with the planned activities at the Bruce Nuclear site for WWMF waste retrieval operations. Indicative commercial labour rates are used for estimating purposes.

10. Locally based commercial trucking service providers are assumed to be utilized on a contract basis to provide the turnkey trucking services necessary to facilitate transportation to an alternate location. Such service providers are assumed to have the requisite tractor/trailer equipment and trained driver resources with the capacity to scale trucking operations up or down as needed consistent with real-time demands for the duration of the project. The availability of such trucking services is not assumed to be a limiting factor. Indicative commercial trucking rates are used for estimating purposes.

11. The cost estimate described in this document is developed consistent with the AACE International guidelines for a Class 5 indicative overview cost estimate[5]. A high-level top-down, lump-sum, aggregate unit rate costing methodology is used based on process knowledge, past projects and judgment to provide an indication of the approximate cost, as is typical for such early conceptual projects. To obtain an indicative costs estimate that is judged to be realistic, adjustments factors are applied to account for the uncertainties and risks associated with the range of technical and planning assumptions that are made for each waste category. Similarly, a management reserve is included in the total project cost to

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[5] AACE International Recommended Practice No. 18R-97, *"Cost Estimate Classification System – As Applied in Engineering, Procurement, and Construction for the Process Industries"*, dated March 1, 2016.

provide a prudent allowance for the range of project-level unknowns, given the future timeframe and long duration of the project.

12. The estimated costs described in this report are limited to the incremental cost that would be incurred for the packaging of waste for transportation in accordance with CNSC regulations, and truck transport from the WWMF to an alternate location in accordance with MTO regulations, should the DGR not be on the Bruce Nuclear site and require transportation on public roads. Other baseline costs, such as waste retrieval from interim storage at the WWMF, and rendering the waste containers and large components ready for DGR emplacement are not considered incremental costs. Such costs are addressed in OPG's plan for activities at the Bruce Nuclear site as described in Section 1.2.

Other assumptions specific to the waste categories, transport packaging, site operations and truck transport and the associated cost estimating methodology used are provided in the remaining sections of this report.

For the purpose of providing a framework for cost estimating, Table 1-2 lists the basic scope of the work activities that are assumed to be included and those that are excluded for purposes of this study.

1.4 Basic Assumptions for Assessing Risks

For the purpose of this study, to assess the incremental radiological and conventional risks associated with packaging, transporting and off-loading the entire inventory of L&ILW from the WWMF to the alternate location described in Section 2, the following basic assumptions are made:

1. Industry data from past or planned L&ILW transport projects is assumed to provide a representative basis to assess the radiation exposure risks for the subject transport.
2. The affected population is assumed to include the crew members and members of the public along the transportation corridor from the WWMF to the alternate location.
3. To assess the radiation exposure risk to an individual, the number of affected persons in the population is assumed to be proportional to the transport distance in the absence of a specific location and transport routing for the alternate location scenarios.
4. Historical accident frequencies and severities for commercial trucking are assumed to be representative of those that can be expected for the shipment of radioactive waste by truck on public roads.

Table 1-2: Transportation Packaging and Operations Work Activity Assumptions

	At WWMF	On Public Roads	At Alternate Location
Within the Scope of this Estimate	Preparation for Transport Operations • Supply/Maintain Reusable Overpacks for Transport Packaging • Supply Transportable Packaging for Bulk Waste as Needed • Supply/Install/Maintain Site Equipment to Support Transport Operations • Provide Suitable Trucks/Conveyances • Supply Transport Package Securements/Tie-Downs • Mobilization/Demobilization Facilitate Transportation Operations • Receive Waste Containers/Large Component (except for resin liners) • Retrieve Resin Liners from Storage (using shielded transfer equipment) • Install Transport Packaging • Place Transport Package on Truck Conveyance • Secure Transport Package to Truck Conveyance • Prepare Shipping Manifest • Perform Preshipment Surveys, Inspections and Testing • Complete Marking, Labeling and Placarding • Implement Logistics to Initiate a Shipment • Repeat Until Last Package Leaves WWMF	Conduct Transport Operations • Truck Transport Package to Alternate Location • Return Empty Transport Packaging (if reusable) • Return Empty Truck/Conveyance to WWMF • Repeat Until Last Package is Transported from WWMF to Alternate Location	Preparation for Transport Package Receipt • Supply/Install/Maintain Site Equipment to Support Transport Package Receipts • Mobilization/Demobilization Conduct Transport Package Receipt Operations • Perform Receipt Surveys and Inspections • Remove Transport Package Securements • Remove Transport Package from Truck Conveyance • Remove Container/Component from Transport Packaging (if reusable) • Stage and Turnover Container/Component and Records • Prepare Empty Reusable Transport Packagings for Return • Repeat Until Last Package is Received from WWMF
Excluded from this Estimate	Preparation for Transportation • Prepare and Implement Transportation Planning, e.g., Regulatory Compliance, Routing, Scheduling, Training, Communications, Control Systems, etc. • Retrieve Waste Containers from Storage (except as noted above) • Repackage Bulk Waste in New Containers as Necessary • Segment Large Components as Necessary • Stage/Turnover Containers/ Components for Transport Packaging	Facilitate/Monitor Transport Operations • Implement Controls for Conducting Transport Operations, e.g., Communications, Shipment Tracking, Emergency Response Preparedness, etc. • Maintain Title and Regulatory Responsibility for the Waste Throughout • Oversee Transport Operations	Preparation for Container/ Component Repository Emplacement • Stage Disposal-Ready Containers/Components for Emplacement • Overpack Non Disposal-Ready Containers/Components and Stage for Emplacement • Temporarily Store Containers/Components Awaiting Emplacement as Necessary

2. Waste to Be Packaged and Transported

For purposes of this estimate, the radioactive waste that is to be packaged to facilitate transportation and that is to be transported on public roads to an alternate location and off-loaded includes the complete inventory of LLW and ILW residing at the WWMF at the time that the DGR is available to begin emplacements. As discussed in Section 1, this is assumed to be either year 2045 or 2055.

The complete inventory of L&ILW residing at the WWMF includes that generated from the operation of the Pickering, Darlington and Bruce nuclear plants and transported/moved from these sites to the WWMF for decay and interim storage in preparation for final disposition. It also includes some of the L&ILW generated from the refurbishments of these plants. For purposes of this study and estimating incremental costs, this inventory of waste is assumed to include and exclude the following:

1. It includes the nonprocessible L&ILW generated by the operation of all three plants up to 2045/2055 for purposes of this study.
2. For the fuel channel ILW generated by reactor refurbishments:
   - It includes those generated from the previous refurbishment of Bruce Nuclear Units 1 & 2 currently in interim storage at the WWMF that are packaged in DGR-ready but not road transportable containers. It is also assumed to include those generated by the planned refurbishment of Bruce Nuclear Units 3 – 8 for purposes of this study.
   - It includes those generated by the upcoming refurbishment of all four Darlington Nuclear units. These are being packaged at the time of removal in DGR-ready and road transportable containers. Following a 25 year period of decay in interim storage on the Darlington Nuclear site, they are to be transported to the WWMF to await final disposition, where they are assumed to reside for purposes of this study.
   - It excludes those currently in interim storage on the Pickering Nuclear site that are to be dispositioned as part of decommissioning activities.
3. For the large component LLW generated by plant refurbishments:
   - It includes the steam generators and heat exchangers from previous refurbishments of the Bruce Nuclear units currently in interim storage at the WWMF. It is also assumed to include the steam generators from future refurbishments of the Bruce Nuclear units for purposes of this study.
   - It includes the heat exchangers from previous refurbishments of the Pickering Nuclear units currently in interim storage at the WWMF. There are no steam generators from refurbishments of the Pickering or Darlington Nuclear units.

   These large components are to be size/weight-reduced by segmentation as necessary at the time of retrieval to render them DGR-ready as part of the planned activities at the Bruce Nuclear site.

For purposes of this study, the L&ILW inventory at the WWMF are grouped into 12 waste categories, including four LLW categories and eight ILW categories which are generally consistent with those identified in the waste retrieval plan described in Section 1. The waste categories identified in this study, whilst aligned with the planned activities at the Bruce Nuclear site, are specifically established to group the common characteristics of the waste for the purpose of transport packaging and truck transport. This approach is taken to simplify the cost estimating approach utilized in this study.

Much of the bulk waste has been packaged in OPG standard containers or packagings at the reactor sites to facilitate handling/transfer, interim storage and isolation at the WWMF. Some of the waste containers and the large component packagings are DGR-ready to facilitate direct emplacement; some containers are not DGR-ready and will require supplemental disposal packaging. For purposes of this estimate, unless otherwise required to facilitate the transportation of some bulk waste categories, e.g., bulk tile hole liner ILW, the supplemental packaging needed to render the waste containers DGR-ready following transportation is not included in this estimate. This is because it is not considered an incremental cost, e.g., emplacement overpacks for resin liners. In cases where packaging is required to facilitate transportation of bulk waste categories, DGR-ready containers are chosen.

Within each waste category, the bulk waste, waste containers and large components have a broad range of characteristics including physical and radiological properties that are specific to each bulk waste item, waste container and large component in the respective inventory. For purposes of this study, no specific differentiation of these characteristics within a waste category are made to simplify cost estimating. For the determination of packaging bulk waste for transport, representative waste forms and radiological characteristics are used or assumed. For the determination of packaging waste containers for transport, representative waste container(s) from the broad range of waste container types in the inventory are used. For the determination of packaging large components for transport, the characteristics of the steam generator segments and the intact or segmented heat exchangers are generalized. The characteristics used are generally taken from the waste inventory forecast for the DGR project at the Bruce Nuclear site[6].

2.1 Transportation Packaging Approach

In their present state, few of the existing waste containers comply with the rigorous regulations governing packaging for transportation on public roads since this was not anticipated, nor would it be required if the DGR is located on the Bruce Nuclear site. These regulatory requirements include compliance with the Canadian Nuclear Safety Commission's (CNSC's) radioactive materials transportation regulations[7] and the Ministry of Transportation, Ontario (MTO) regulations for road transport by truck[8]. Where feasible, transportation packagings are used that avoid the need to rehandle and repackage the bulk waste and the associated exposures and risks. Also, transportation packagings are used that avoid the need for oversized and /or overweight permitted shipments.

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[6] OPG 00216-REP-03902-00003, "Reference Low and Intermediate Level Waste Inventory for the Deep Geologic Repository", Rev. 003, December 2010.

[7] Canadian *"Packaging and Transport of Nuclear Substances Regulations, 2015"*, (SOR/2015-145), referred to as the CNSC PTNSR, which incorporates by reference the International Atomic Energy Agency SSR-6 Regulations, "*Regulations for the Safe Transport of Radioactive Material*," 2012.

[8] Ministry of Transportation Ontario, Highway Traffic Act, Ontario Regulation 413/05, "Vehicle Weights and Dimensions – for Safe, Productive and Infrastructure Friendly Vehicles," November 29, 2016.

For purposes of this estimate, multiple LLW waste containers are placed in compatible commercially available freight containers that are qualified as a transport compliant packaging and that are reusable, including the waste containers retrieved from the Low Level Storage Buildings (LLSBs) and those from bulk trench waste repackaging as part of retrieval. This approach facilitates more efficient transport of these wastes compared with transporting individual waste containers, many of which are not transportable since this was not anticipated. The supply of these freight containers is included in this estimate.

For the large component LLW, i.e., steam generators and some heat exchangers, the bulk components are assumed to be segmented/cut when necessary to reduce their size and weight for DGR emplacement, and consequently for transportation. The cost of large component segmentation is not included in this estimate since it is not considered an incremental cost as it would be required to facilitate emplacement in any case.

It is assumed that the steam generator segments are prepared in such a way that establishes a compliant self-packaging for transportation, (in addition to being DGR-ready). For purposes of this estimate, the design and supply of a supplemental soft packaging for each self-packaged steam generator segment are included. The size and weight of some of the heat exchangers are such that they can be transported intact. Both the segmented or intact heat exchangers are assumed to be overpacked in suitable reusable freight containers to facilitate transport. The cost for modifications to the design of such freight containers as may be necessary and the supply of these containers are included in this estimate.

For some ILW categories, such as the resin liners and the new containers for the tile hole liner bulk waste, reusable shielded flasks or overpacks similar to existing designs are used to facilitate packaging for transport. These flasks and overpacks are needed to establish Type B packaging capability. As part of the retrieval process for the tile hole liner ILW, it is assumed that the bulk waste is removed from the liners and packaged in new containers that are suitable for transport, (and that are also DGR-ready). This approach is taken since the tile hole liners (whether removable or fixed) and the varied configuration of the bulk waste in these liners do not easily lend themselves to be rendered transportable by reasonable means. The cost for supply of these transport flasks and overpacks, and the new transportable containers for bulk tile hole waste are included in this estimate.

For the ILW packaged in the Darlington Retube Waste Containers (RWCs), it is assumed that only supplemental packaging, i.e., impact limiters, are needed to render these containers transportable. The cost for supply of these impact limiters is not included in this estimate, as Darlington RWCs need to be transported regardless of the DGR location. For the ILW packaged in Bruce RWCs and grouted tile holes, a compatible transport packaging design does not exist in the industry since transportation of these was not anticipated. For the Bruce RWCs and grouted tile holes, new transport overpack designs that establish Type B packaging capability are assumed consistent with their configuration and weight. The cost for such new or modified designs, CNSC certification (in the case of Type B packagings), and the supply of these transport overpacks are included in this estimate.

2.2 Transport Packaging Requirements

A fundamental underpinning of the regulations that ensure the safe transportation of radioactive materials on public roads is compliance with the rigorous standards for packaging of such materials. A high reliance is placed on the transport packaging to be the primary barrier to ensure that all radioactive material is contained/confined to limit dose rates during normal conditions of transport, and to limit the potential release of radioactive material during accident conditions. The CNSC transportation regulations, i.e., the CNSC Packaging and Transport of Nuclear Substances Regulations (PTNSR), establish transportation packaging standards based on the characteristics and potential hazard posed by the different types of nuclear material, regardless of the mode of transport.

These regulations set out performance standards for different transportation package applications, and set the criteria for design compliance according to both the activity and the physical form of the radioactive material. Principal among these are the unshielded dose rate and the quantities of radionuclides for the radioactive material which are used to establish the degree of transportation packaging required and the associated activity limits for the packaging contents. Based on these, the regulations utilize a graded approach to transportation package safety with a range of packaging compliance standards specified. As they apply to this application, they range from standards for high integrity packagings that are suitable for lower activity waste to more robust packagings that are suitable for higher activity waste. These include the Excepted, Industrial, Type A and Type B transportation packaging standards.

For purpose of this estimate, the applicable waste packaging standards specified by the transportation regulations are used which include the following:

1. Excepted Package: Designation that is used when the packaging contents are below radiological concern. For purposes of this estimate, this transportation packaging standard is applied to the return shipment of empty reusable transport packagings from the alternate location back to the WWMF.

2. Industrial Package Type 2 (Type IP-2): An industrial packaging type used for transporting low specific activity (LSA) waste and surface contaminated object (SCO) waste. Industrial packagings used for transporting LSA material and SCO are not required to withstand transport accidents. Geometrical changes of LSA material or SCO as a result of an accident are not expected to lead to a significant increase in the external radiation level. The Type IP-2 packaging standard limits the radiation level at a distance of 3 m from the unshielded waste to 10 mSv/h which effectively limits the potential external dose for severe accidents to acceptable levels. For purposes of this estimate, the IP-2 transportation packaging standard is applied for shipment of most of the LLW inventory.

3. Type A Package: A packaging type used for transporting a limited but significant quantity of medium activity waste. The Type A packaging standard limits the total radionuclide quantities to the A_2 values specified in the CNSC PTNSR. The shielding of a Type A package is assumed to be completely lost in a severe accident. The dose rate at a distance of 1 m from the edge (or surface) of the unshielded radioactive contents is limited to 100 mSv/h which effectively limits the potential external dose for severe accidents to acceptable levels. For purposes of this estimate, the Type A transportation packaging standard is applied for shipment of the higher activity LLW and lower activity ILW.

4. Type B Package: A packaging type used for transporting larger quantities of higher activity waste. A Type B packaging is required when the total radionuclide quantities exceed the A_2 values specified in the CNSC PTNSR. In addition to meeting the standards for a Type A packaging, a Type B packaging must also provide a high degree of assurance that package

integrity will be maintained even during severe accidents with essentially no loss of the radioactive contents or serious impairment of the shielding capability. They range from heavily shielded flasks to robust overpacks that maintain containment and shielding functions, even under extreme accident conditions. Type B packaging must satisfy the stringent requirements and testing criteria specified by the regulations and the designs are certified by national authorities such as the CNSC. The testing criteria for Type B packagings were developed to simulate conditions of severe hypothetical accidents, including impact, puncture, fire, and immersion in water. For purposes of this estimate, the Type B transportation packaging standard is applied for shipment of the higher activity ILW.

All of the above transportation packaging standards limit the radiation dose rates during normal conditions of transport to the following:

- ≤ 2 mSv/h (200 mrem/h) at any point on the external surface of the package
- ≤ 0.1 mSv/h (10 mrem/h) at any point 2 m (6.6 ft) from the vertical planes projected by the outer lateral surfaces of the vehicle/conveyance.
- ≤ 0.02 mSv/h (2 mrem/h) in any normally occupied position in the vehicle for vehicle operation.

For the purpose of this study, no specific waste category activation data are developed and no radiological decay calculations are performed. For purposes of transport packaging determination, significant radiological decay can be expected based on the +30 to +60 year period into the future that the shipments would occur, in addition to the decay time which has already occurred for the waste since the waste was generated. Given this and engineering judgment, the following general transport packaging assumptions are made:

- For all LLW, 90% qualifies for Type IP-2 packaging, with the remaining 10% requiring Type A packaging.
- Except for fuel channel waste, 70% of all ILW requires Type B packaging, with the remaining 30% qualifying for Type A packaging.
- For existing fuel channel ILW, 50% requires Type B packaging, with the remaining 50% qualifying for Type A packaging. For fuel channel ILW generated by future reactor refurbishments, 100% requires Type B packaging.

2.3 Waste Category and Packaging Descriptions

The WWMF shown in Figure 2-1 provides interim storage for the radioactive waste generated by the operation of the Pickering, Darlington and Bruce Nuclear plants, as described at the beginning of Section 2. For purposes of this estimate, the WWMF inventory is assumed to be comprised of four waste categories that are LLW and the eight waste categories that are ILW, including bulk waste, waste containers and large components, and the associated transport packagings, as described in the sections that follow.

Figure 2-1: Aerial View of WWMF

2.3.1 *Low Level Waste Categories*

2.3.1.1 Low Level Storage Building Containers – L&ILW DGR-Ready

Consistent with the planned activities at the Bruce Nuclear site, the LLW at the WWMF in years 2045 and 2055 is assumed to include the LLSBs' waste containers. The LLSBs provide interim storage for a broad range of LLW container types, including ash bins, compactor boxes, non-pro boxes, drums, resin and sludge boxes, resin pallet tanks and miscellaneous large objects. The contents of these containers is non-processible waste such as ion exchange columns, scaffolding, piping, shavings, angle irons, etc.

Figure 2-2: L&ILW DGR-Ready Model NPB47 Non-Pro Box

As of year 2000, the DGR-ready Model NPB47 non-pro box shown in Figure 2-2 has become the preferred LLW container. Consistent with the planned activities at the Bruce Nuclear site, it is assumed that the other container types in the LLSBs are overpacked or their bulk waste contents are transferred to Model NPB47 non-pro boxes, as part of the retrieval process. For purposes of this estimate, this non-pro box is assumed to be representative in terms of size, weight and contents of all the LLSB waste container types to be transported, other than those described in Section 2.3.1.2.

On this basis, it is estimated that about 35,105 such non-pro box waste containers are retrieved from the LLSBs for transport packaging and truck transport for the 100 km and 300 km transport distances beginning in 2045. Similarly, 38,287 such non-pro box waste containers are retrieved from the LLSBs for transport packaging and truck transport for the 200 km and 2,000 km transport distances beginning in 2055.

The Model NPB47 non-pro box has a tube and angle structural frame with sheet metal sides and bottoms. These box containers are typically handled with a forklift. The net cavity volume of this waste container is 2.5 m^3. The expected total volume of LLSB waste in Model NPB47 non-pro boxes are estimated to be about 87,763 m^3 in 2045 and 95,716 m^3 in 2055.

For purposes of this estimate, it is assumed that 90% of the Model NPB47 non-pro boxes retrieved from the LLSBs are LSA waste at the time of shipment and are packaged for transport in a 40 foot (12.2 m) unshielded Type IP-2 freight container similar to that shown in Figure 2-3. The remaining 10% are assumed to be Type A waste at the time of shipment and are packaged in a similar 40 foot (12.2 m) shielded Type A freight container (not shown). Each 40 foot transport packaging can accommodate up to eight such non-pro boxes. The total number of shipments required to transport the LLSB waste category in Model NPB47 non-pro box containers is estimated to be about 6,150 for the 2045 transport distances and 6,508 for the 2055 transport distances.

Figure 2-3: 40 ft. Type IP-2 Transport Packaging for Model NPB47 Non-Pro Boxes

2.3.1.2 Low Level Storage Building Containers – Other

As described in Section 2.3.1.1, the LLSBs at the WWMF store a wide variety of LLW container types. Among these are 6,437 Model NPB4 non-pro bins shown in Figure 2-4 that are not DGR-ready, and 5,790 that are DGR-ready, for a total of 12,227. The last of these was loaded in year 2000. These legacy non-pro bins are to be rendered DGR-ready at the L&ILW DGR prior to emplacement. For purposes of this estimate, it is assumed that the entire inventory of Model NPB4 non-pro bins are retrieved from the LLSBs and packaged for transport as-is.

Figure 2-4: Model NPB4 Non-Pro Bins

The Model NPB4 non-pro bins have an angle structural frame with corrugated sheet metal sides and bottoms and are somewhat larger than the Model NPB47 non-pro box described in Section 2.3.1.1. The net cavity volume of this waste container is 3.2 m^3. These bin containers are typically handled with a forklift. The expected total volume of LLSB waste in Model NPB4 non-pro bins are estimated to be about 39,126 m^3 in both 2045 and 2055.

For purposes of this estimate, it is assumed that 90% of the Model NPB4 non-pro bins retrieved from the LLSBs are LSA waste at the time of shipment and are packaged for transport in a 48 foot (14.6 m) unshielded Type IP-2 freight container similar to that shown in Figure 2-5. The remaining 10% are Type A waste at the time of shipment and are packaged in a similar 48 foot (14.6 m) shielded Type A freight container (not shown). Each 48 foot transport packaging can accommodate up to five such non-pro bins.

Figure 2-5: 48 ft. Type IP-2 Transport Packaging for Model NPB4 Non-Pro Bins

The total number of shipments required to transport the LLSB waste category in Model NPB4 non-pro bin containers is estimated to be about 2,446 for all 2045 and 2055 transport distances.

2.3.1.3 Bruce Steam Generators

Figure 2-6: Steam Generator from Bruce A Station

Consistent with the planned activities at the Bruce Nuclear site, the large component SCO waste at the WWMF in years 2045 and 2055 is assumed to include 64 steam generators (SGs), 32 each from the Bruce A and Bruce B stations, similar to that shown in Figure 2-6. During the retrieval process, these bulk SGs are to be segmented at the WWMF to reduce their size and weight to a sufficient degree to render them compatible with the DGR. Each Bruce A & B SG is to be size/weight reduced into 5 and 8 segments, respectively, resulting in a total of 416 segments.

Figure 2-7: Typical Steam Generator Supplemental Soft Transport Packaging

The gross volume and weight of the bulk Bruce A SGs are about 56 m^3 and 88,000 kg each, respectively. Similarly, the gross volume and weight of the bulk Bruce B SGs are about 131 m^3 and 135,000 kg. The waste SGs materials include the carbon steel shell and the internal high alloy steel tubes. The total gross volume of SG materials is about 5,984 m^3.

Figure 2-8: Typical Steam Generator Oversized Hard Transport Packaging

The range of SG segment sizes are expected to be between 2.5 to 3.6 m in diameter and 1.94 to 2.9 m in length, with the Bruce B SG segments having the largest diameter. The range of SG segment weights are expected to be between 19,718 to 33,686 kg with the Bruce A SG segments generally being heavier. It is assumed that 90% of the SG segments are SCO waste and 10% are Type A waste at the time of shipment for purposes of this estimate.

As part of the SG segmentation process, the SG segment openings are sealed with welded steel plates and the SG segment is grouted. The as-segmented, sealed and grouted waste SGs provide sufficient self-packaging to be DGR-ready. For purposes of this estimate, the as-segmented and prepared SG segments are assumed to be sufficiently self-packaged to meet either Type IP-2 or Type A packaging standards consistent with their classification. For transport purposes, a supplemental soft packaging is installed on each SG segment, similar to that shown in Figure 2-7, rather than a custom oversized hard packaging similar to that shown in Figure 2-8. Each SG segment is shipped individually.

The total number of shipments to transport the Bruce steam generators is estimated to be about 416 for all 2045 and 2055 transport distances.

2.3.1.4 Trench Waste

Consistent with the planned activities at the Bruce Nuclear site, the LLW at the WWMF in 2045 and 2055 is assumed to include that in the trench waste storage units shown in Figure 2-9. The trench waste storage units currently store a range of non-processible bulk LLW, including drums, filters, bagged waste, plywood boxes, shield plugs, ash and sludge containers, tile holes, smaller heat exchangers, and other miscellaneous objects, similar to that shown in Figure 2-10.

Figure 2-9: Trench Waste Storage Units

During the retrieval process, this bulk trench waste is to be packaged in Model NPB47 non-pro boxes, as described in Section 2.3.1.1, and Model DBIN1 drum bins shown in Figure 2-11, both of which are DGR-ready. The total number of these trench waste containers is estimated to be 1,926, including 1,494 non-pro boxes and 432 drum bins.

Figure 2-10: Typical Bulk Waste in Trench Storage Units

The Model NPB47 non-pro box is described in Section 2.3.1.1. The Model DBIN1 drum bin is similar in size and construction to the non-pro box. The net volume of the drum bin is 1.9 m^3. The total volume of trench waste is estimated to be about 4,556 m^3.

For purposes of this estimate, it is assumed that 90% of the trench waste containers are LSA waste at the time of shipment and are packaged for transport in a 40 foot (12.2 m) unshielded Type IP-2 freight container similar to that shown in Figure 2-3 described in Section 2.3.1.1. The remaining 10% are assumed to be Type A waste at the time of shipment and are packaged in a similar 40 foot (12.2 m) shielded Type A freight container (not shown). Each 40 foot transport packaging can accommodate up to eight trench waste containers.

The total number of shipments to transport the trench waste containers is estimated to be about 241 for all 2045 and 2055 transport distances.

Figure 2-11: L&ILW DGR-Ready Model DBIN1 Drum Bins

2.3.1.5 Heat Exchangers

Consistent with the planned activities at the Bruce Nuclear site, the large component SCO waste at the WWMF in years 2045 and 2055 is assumed to include 41 Heat Exchangers (HX) similar to those shown in Figure 2-12, which are currently stored below grade (not shown). Of these, 10 are to be segmented at the WWMF during the retrieval process to reduce their size and weight to a sufficient degree to render them compatible with the DGR resulting in 20 HX segments. The remaining 31 do not require segmentation and are to remain intact.

Figure 2-12: Typical Heat Exchanger Large Component

Figure 2-13: Standard 20 ft. Type IP-2 Transport Packaging to Be Modified for Heat Exchanger Segments

Figure 2-14: Standard 20 ft. Type A Transport Packaging to Be Modified for Heat Exchanger Segments

The gross volume and weight of these HXs vary between 16 to 51 m^3 and 8,000 to 35,000 kg, respectively. The total volume of HX waste is estimated to be about 1,160 m^3. The waste HX materials include the carbon steel shell and the internal alloy steel tubes.

The outside diameter and length of the HXs range from 0.91 to 2.95 m and 4.57 to 7.62 m, respectively. The 10 HXs that require segmentation exceed 2.44 m in diameter, 6.55 m in length and 27,000 kg in weight. Similarly, the 31 smaller HXs that do not require segmentation and can remain intact range from 0.91 to 1.83 m in diameter, 1.52 to 7.62 m in length, and 8,000 to 20,000 kg in weight.

For purposes of this estimate, it is assumed that 90% of the HXs are SCO waste 10% are Type A waste at the time of shipment. The intact HXs that are SCO waste are packaged for transport in a 40 foot (12.2 m) unshielded Type IP-2 freight container similar to that described in Section 2.3.1.1 and shown in Figure 2-3. The intact HXs that are Type A waste are packaged in a similar 40 foot (12.2 m) shielded Type A freight container (not shown). Given their size, the HX segments that are SCO waste are packaged in a custom designed oversized unshielded Type IP-2 container that is 20 foot (6.09 m) long, which is assumed to be an oversized version of that shown in Figure 2-13. The HX segments that are Type A waste are packaged in a custom designed oversized shielded Type A container that is 20 foot (6.09 m) long, which is assumed to be an oversized version of that shown in Figure 2-14. The total number of shipments to transport the heat exchangers is estimated to be about 51 for all 2045 and 2055 transport distances.

2.3.2 *Intermediate Level Waste Categories*

2.3.2.1 IC-2 Tile Holes with Fixed Liners Waste

Consistent with the planned activities at the Bruce Nuclear site, the ILW at the WWMF in years 2045 and 2055 is assumed to include the bulk waste in the IC-2 Tile Hole Liner (THL) storage units with a fixed internal liner, as shown in Figure 2-15. Each of the fixed liner THLs contains approximately 2.15 m^3 of non-processible bulk ILW, including filter vessels, ion exchange vessels, irradiated core components, cartridge filter elements, and other miscellaneous waste. The volume of bulk waste from all 20 fixed liner THLs is estimated to be about 43 m^3.

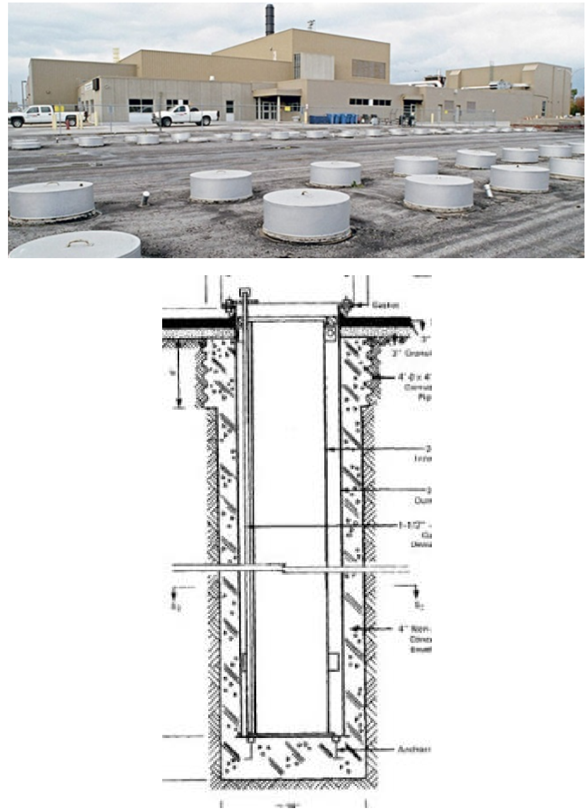

Figure 2-15: IC-2 THL Storage Units with Bulk Waste in Fixed Liners

For purposes of this estimate, it is assumed that, the bulk waste removed from these fixed liner THLs is packaged in new shielded containers, such as ES's Modular Shielded Container (MSC) shown in Figure 2-16, as part of the retrieval process. The MSC is a robust packaging that is designed to be transportable as a Type A packaging and is considered DGR-ready. For Type B shipments, the MSC is placed in a reusable MSC Type B transport overpack with impact limiters as shown in Figure 2-16, with shielding provided by the MSC itself.

The dimensions of the cuboidal shaped MSC are 2.27 m OL x 1.84 m OW x 1.73 m OH, with a nominal tare weight of 20,000 to 27,000 kg depending on shielding thickness. For purposes of this estimate, it is assumed that MSCs with either 4 inch or 6 inch shielding inserts are supplied. The dimensions of the MSC Type B overpack are 3.05 m OL x 2.61 m OW x 2.53 m OH.

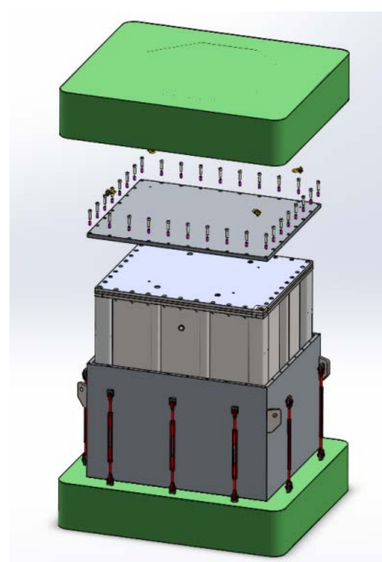

Figure 2-16: MSC in Type B Transport Packaging for IC-2 THL Waste

For the purposes of this estimate, it is assumed that 70% of the fixed liner THL waste in MSCs is Type B waste at the time of shipment that require the MSC Type B transport overpack. The remaining 30% is Type A waste and the MSC alone as a Type A transport packaging is sufficient. Type B packages are shipped one at a time. It is also assumed that the Type A packages are shipped one at a time, although for some shipping two at a time may be feasible subject to seasonal road restrictions.

Assuming a 20% reduction in packaging density/efficiency for the fixed liner THL bulk waste, the total number of MSC shipments to transport the IC-2 THL with fixed liner waste is estimated to be about 17 for all 2045 and 2055 transport distances.

2.3.2.2 IC-2 Tile Holes with Removable Liners Waste

Consistent with the planned activities at the Bruce Nuclear site, the ILW at the WWMF in years 2045 and 2055 is assumed to include the bulk waste in 181 IC-2 Tile Hole Liner (THL) storage units with a removable internal liner, as shown in Figure 2-17. Each of these removable liner THLs contains approximately 0.95 m^3 of non-processible bulk ILW including filter vessels, ion exchange vessels, irradiated core components, cartridge filter elements, and other miscellaneous waste. The volume of waste from all these removable liner THLs is estimated to be about 172 m^3.

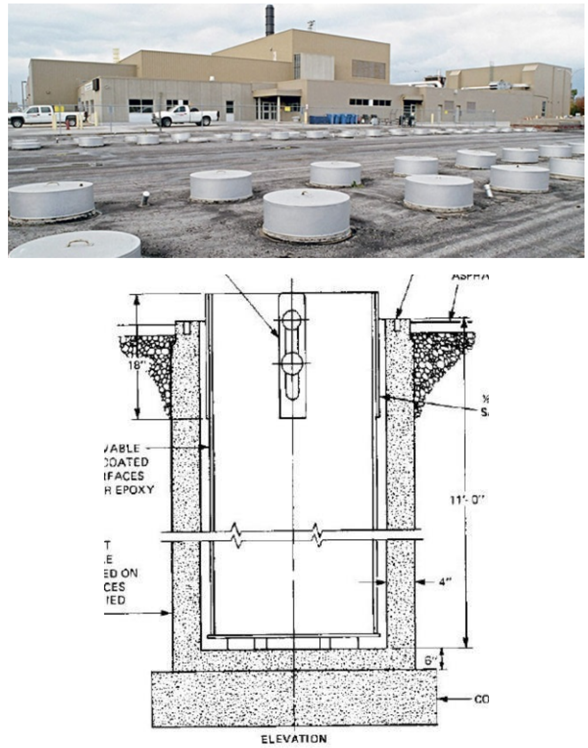

Figure 2-17: IC-2 THL Storage Units with Bulk Waste in Removable Liners

For purposes of this estimate, it is assumed that as part of the retrieval process, the bulk waste from these removable liner THLs is packaged in shielded containers that are transportable and considered DGR-ready, such as the MSC described in Section 2.3.2.1 and shown in Figure 2-18.

For the purposes of this estimate, it is assumed that 70% of the removable liner THL bulk waste in MSCs is Type B waste at the time of shipment that require the MSC Type B transport overpack, as described in Section 2.3.2.1 and shown in Figure 2-18. The remaining 30% is Type A waste and the MSC alone as a Type A transport packaging is sufficient, as described in Section 2.3.2.1. Type B packages are shipped one at a time. It is also assumed that the Type A packages are shipped one at a time, although for some shipping two at a time may be feasible subject to seasonal road restrictions.

Assuming a 20% reduction in packaging density/efficiency for the removable liner THL bulk waste, the total number of MSC shipments to transport the IC-2 THL with removable liner waste is estimated to be about 66 for all 2045 and 2055 transport distances.

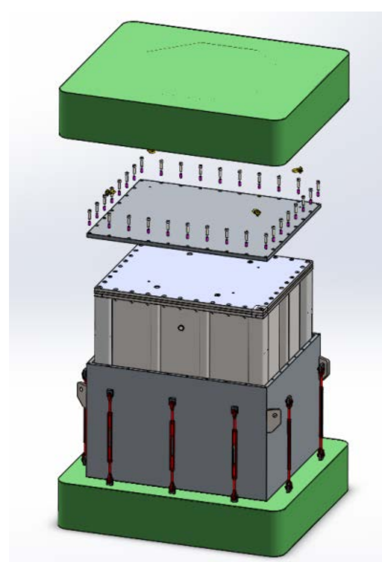

Figure 2-18: MSC in Type B Transport Overpack for IC-2 THL Waste

2.3.2.3 Quadricell Resin Liners

Consistent with the planned activities at the Bruce Nuclear site, the ILW at the WWMF in years 2045 and 2055 is assumed to include 115 resin liners (RLs) in the quadricell storage units as shown in Figure 2-19. The RLs in each quadricell are stacked two high in a 2 x 2 array. Each quadricell RL contains approximately 3 m^3 of dewatered ion exchange resin. The carbon steel RL is 1.63 m OD x 1.8 m OH and weighs about 4,500 kg. These RLs are overpacked in 1.68 m OD x 1.91 m OH stainless steel liners with a combined gross weight of 6,000 kg.

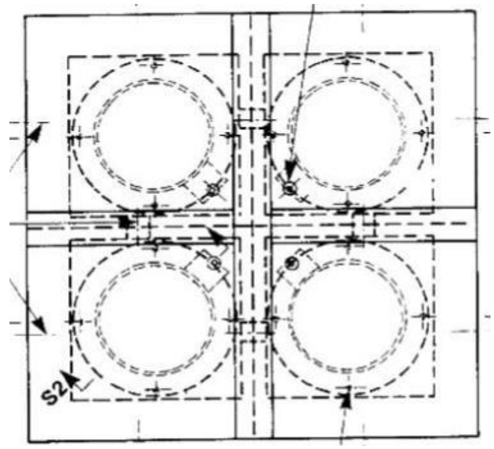

Figure 2-19: Quadricell Storage Units with Resin Liners

For purposes of this estimate, it is assumed that each unshielded overpacked RL is retrieved from a quadricell storage unit individually using a shielding bell similar to that shown in Figure 2-22, and transferred to the transport packaging.

Figure 2-20: Type B Transport Packaging for Quadricell Resin Liner

For the purposes of this study, it is assumed that 70% of the quadricell RLs are Type B waste at the time of shipment, with the remaining 30% being Type A waste. In the Type B transport packaging configuration, a RL is transferred into an OPG Trillium flask shown in Figure 2-20, which is a robust Type B lead shielded flask. The outside dimensions of this Type B packaging are 2.59 m OD x 3.30 m OH.

Figure 2-21: Type A Transport Packaging for Quadricell Resin Liners

In the Type A transport packaging configuration, RLs are transferred one at a time into a suitable shielded Type A freight container similar to that shown in Figure 2-21, which has a capacity for three RLs each. Only two RLs are assumed to be loaded to maintain the weight of the Type A package within legal limits. The outside dimensions of this Type A freight container are 6.06 m L x 2.44 m W x 2.59 m H. The total number of shipments to transport the quadricell resin liners is estimated to be about 98 for all 2045 and 2055 transport distances.

Figure 2-22: Typical Resin Liner Shielding Bell

2.3.2.4 IC-18 Tile Hole Equivalent Liner Waste

Consistent with the planned activities at the Bruce Nuclear site, the ILW at the WWMF in years 2045 and 2055 is assumed to include the bulk waste in IC-18 storage units with Tile Hole Equivalent Liners (THEL) as shown in Figure 2-23. A total of 604 THELs are estimated by 2045 and 685 THELs by 2055. Each THEL contains approximately 2.66 m^3 of non-processible bulk ILW including ion exchange vessels, irradiated core components, cartridge filter elements, and other miscellaneous waste. The total volume of bulk waste in all THELs is estimated to be 1,607 m^3 in 2045 and 1,822 m^3 in 2055.

The bulk waste is assumed to be removed from the IC-18 THELs as part of the retrieval process and packaged in shielded containers that are transportable and considered DGR-ready, such as the MSC described in Section 2.3.2.1 and shown in Figure 2-24.

For purposes of this estimate, it is assumed that 70% of the bulk THEL waste are Type B waste at the time of shipment, with the remaining 30% being Type A waste. The Type B waste will be shipped in an MSC with a Type B MSC transport packaging, while the Type A waste can be shipped in the MSC alone. Type B packages are shipped one at a time. It is also assumed that the Type A packages are shipped one at a time, although for some shipping two at a time may be feasible subject to seasonal road restrictions.

Assuming a 20% reduction in packaging density/efficiency for the bulk waste from IC-18 THELs, the total number of MSC shipments to transport the IC-18 THEL waste are estimated to be about 616 for the 2045 transport distances and 698 for the 2055 transport distances.

Figure 2-23: IC-18 Storage Units with Bulk Waste in THELs

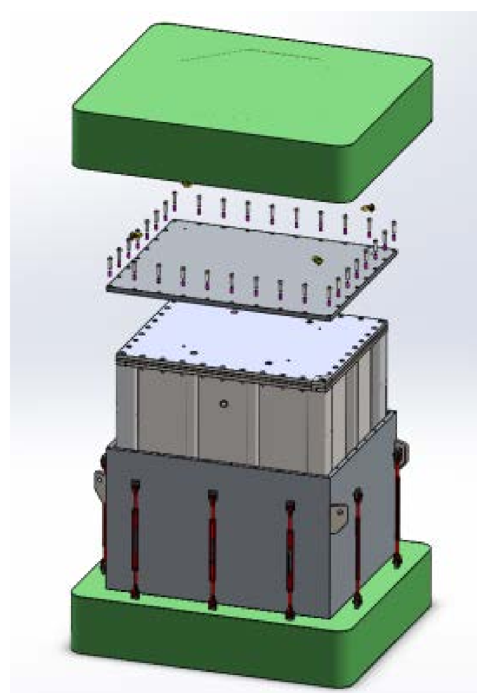

Figure 2-24: Transport Packaging for IC-18 Waste

2.3.2.5 IC-12/IC-18 Resin Liners

Consistent with the planned activities at the Bruce Nuclear site, the ILW at the WWMF in years 2045 and 2055 is assumed to include resin liners (RLs) stored in the IC-12 and IC-18 storage units shown in Figure 2-25. A total of 2,083 RLs are estimated by 2045 and 2,289 are estimated by 2055. The RLs in each IC-12/IC-18 storage unit are stacked several high. Each RL contains approximately 3 m^3 of dewatered ion exchange resin.

As shown in Figure 2-25, the IC-12/IC-18s have a combination of carbon steel RLs that are not overpacked, carbon steel RLs that are overpacked as described in Section 2.3.2.3, and stainless steel RLs that are not overpacked. These stainless steel RLs are 1.63 m OD x 1.80 m OH with a gross weight of 4,500 kg.

For purposes of this estimate, it is assumed that each unshielded RL, (overpacked and not overpacked), is retrieved from a IC-12/IC-18 storage unit individually using a shielding bell as described in Section 2.3.2.3, and transferred to the transport packaging.

For the purposes of this study, it is assumed that 70% of the IC-12/IC-18 RLs are Type B waste, at the time of shipment with the remaining 30% being Type A waste. In the Type B transport packaging configuration, one RL is transferred into the OPG Trillium flask shown in Figure 2-26 and described in Section 2.3.2.3. In the Type A transport packaging configuration, RLs are transferred one at a time into a suitable shielded Type A freight container similar to that shown in Figure 2-27, and described in Section 2.3.2.3. Only two RLs are assumed to be loaded to maintain the weight of the Type A package below legal limits.

The total number of shipments to transport the IC-12/IC-18 resin liners are estimated to be about 1,771 for the 2045 transport distances and 1,946 for the 2055 transport distances.

Figure 2-25: IC-18 Storage Units and Carbon Steel Resin Liner, Stainless Steel Overpack and Stainless Steel Resin Liner

Figure 2-26: Type B Transport Packaging for IC-12/IC-18 Resin Liner

Figure 2-27: Type A Transport Packaging for IC-12/IC-18 Resin Liners

2.3.2.6 Grouted Tile Hole Waste

Consistent with the planned activities at the Bruce Nuclear site, the ILW at the WWMF in years 2045 and 2055 is assumed to include waste stored in 43 tile hole storage units similar to those described in Section 2.3.2.1 without a steel liner. These tile holes contain waste that is similar to that stored in the THELs described in Section 2.3.2.4. As part of the retrieval process, these tile holes are to be grouted to encapsulate the waste, and then the tile hole is to be extracted from the ground intact into a steel pipe, similar to that shown in Figure 2-28. The dimensions of the extracted grouted encapsulated tile hole (ETH) are 1.5 m OD x 4.6 m OL. The weight of each ETH is nominally 25,000 kg.

Figure 2-28: Similar Extracted Encapsulated Tile Hole

For the purposes of this estimate, it is assumed that 70% of ETHs are Type B waste at the time of shipment, with the remaining 30% being Type A waste. In the Type B transport packaging configuration, an ETH is placed in a unique custom designed, reusable Type B overpack with impact limiters, shown conceptually in Figure 2-29. The outside dimensions of this ETH Type B transport package is 2.56 m OD x 5.80 m OL, with adequate shielding assumed to be provided by the grouted tile hole itself. In the Type A transport packaging configuration, an ETH is placed in a reusable 20 foot Type A intermodal freight container similar to that shown in Figure 2-30. The outside dimensions of this Type A intermodal freight container are 6.06 m L x 2.44 m W x 1.98 m H. The ETHs are packaged and shipped one at a time.

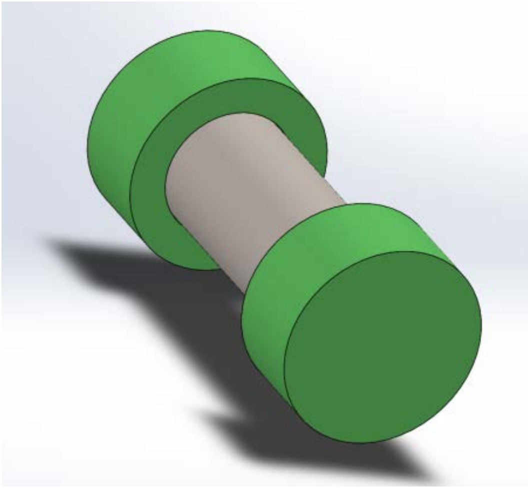

Figure 2-29: Conceptual Type B Transport Packaging for Extracted Encapsulated Grouted Tile Hole

The total number of shipments to transport the grouted tile holes is estimated to be 43 for all 2045 and 2055 transport distances.

Figure 2-30: Type A Transport Packaging for Extracted Encapsulated Tile Hole

2.3.2.7 Bruce Retube Waste Containers – Units 1 to 8

Consistent with the planned activities at the Bruce Nuclear site, the ILW at the WWMF in years 2045 and 2055 is assumed to include the Bruce Retube Waste Containers (RWCs) for fuel channel waste, including the existing RWCs from the refurbishment of Units 1 & 2, and the future RWCs that are needed for the planned refurbishments of Units 3-8. The refurbishment of each Bruce unit generates about 96 m^3 of End Fitting (EF) waste, 10.77 m^3 of Pressure Tube (PT) waste, 7.17 m^3 of Calandria Tube (CT) waste, and 1 m^3 of Calandria Tube Insert (CTI) waste. The total volume of fuel channel waste packaged in RWCs for all eight Bruce units is estimated to be 920 m^3.

Figure 2-31: Bruce Units 1 & 2 RWC for EFs

Two types of RWCs are used for Bruce Units 1 & 2 including a larger less heavily shielded RWC configured for bulk EFs shown in Figure 2-31, and a smaller more heavily shielded RWC configured for volume reduced PTs/CTs and bulk CTIs shown in Figure 2-32. Both of these RWC types are robust shielded containers that are designed to be DGR-ready but have not been qualified as transport packagings. The RWC for EFs has external dimensions of 3.35 m OL x 1.70 m OW x 1.92 m OH with a maximum gross weight of 33,500 kg. The RWC for PTs/CTs/CTIs has external dimensions of 1.85 m OL x 1.85 m OW x 2.25 m OH with a maximum gross weight of 29,100 kg.

Figure 2-32: Bruce Units 1 & 2 RWC for PT/CT/CTs

For Bruce Units 1 & 2, there are a total of 178 RWCs, including 102 RWCs for EFs and 76 RWCs for PT/CT/CTIs. The fuel channel waste from the Bruce Units 1 & 2 refurbishment will have been decayed in interim storage for over 40 years by 2045 and 50 years by 2055.

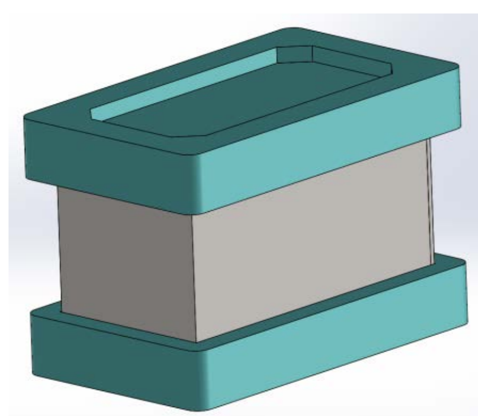

Figure 2-33: Conceptual Type B Overpack for Transport of Bruce EF-RWCs

For purposes of this estimate, it is assumed that 50% of the PT/CT RWCs for Units 1 & 2 are Type B waste and 50% are Type A waste at the time of shipment, and 100% of the EF RWCs for Units 1 & 2 are Type A waste. The RWCs that are Type B waste are packaged for transport using unique custom designed stainless steel Type B overpacks with impact limiters. The two separate Type B overpacks are designed, one for a RWC with EFs shown conceptually in Figure 2-33, and one for a RWC with PT/CT/CTIs shown conceptually in Figure 2-34 They have external dimensions of approximately 4.01 m OL x 2.36 m OW x 2.66 m OH and 2.52 m OL x 2.52 m OW x 2.98 m OH, respectively. It is assumed that adequate shielding is provided by the RWC itself. It is further assumed that the RWCs that are Type A waste can be qualified as a Type A transport packaging and shipped as-is without supplemental packaging.

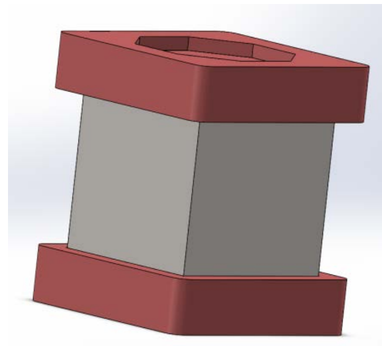

Figure 2-34: Conceptual Type B Overpack for Transport of Bruce PT/CT/CTI-RWCs

The RWCs for Bruce Units 3-8 have not yet been designed and refurbishment of these units has not yet begun. For the purpose of this estimate, it is assumed that refurbishment of Units 3-8 generates the same types and volumes of fuel channel waste as Units 1 & 2. It is further assumed that the RWCs for Units 3-8 will be comparable to those for Units 1 & 2. Thus, the RWCs for Units 3-8 are assumed to be packaged for transport and shipped in the same manner as the RWCs for Unit 1 & 2 described above, except that all the RWCs for Units 3-8 are assumed to be Type B waste at the time of shipment and require Type B transport packaging. This is because their decay time in interim storage will be at least 25 years, but it is much shorter compared with that for Units 1 & 2.

The total number of RWC shipments (one per shipment) to transport Bruce RWCs for all eight Bruce units is estimated as follows for all 2045 and 2055 transport distances:

- 306 Type B shipments for RWCs with EF waste
- 102 Type A shipments for RWCs with EF waste
- 266 Type B shipments for RWCs with PT/CT/CTI waste
- 38 Type A shipments for RWCs with PT/CT/CTI waste

2.3.2.8 Darlington Retube Waste Containers – Units 1 to 4

Consistent with the planned activities at the Bruce Nuclear site, the ILW at the WWMF in years 2045 and 2055 is assumed to include the Darlington RWCs shown in Figure 2-35, for the fuel channel waste from the upcoming refurbishment of the Unit 1-4 reactors. The Darlington fuel channel waste includes End Fittings (EFs), Pressure Tubes (PTs), Calandria Tubes (CTs), Calandria Tube Inserts (CTIs). The design of the Darlington RWC (D-RWC) is completed but refurbishment of the Darlington reactors has not yet begun. The total volume of fuel channel waste generated by the refurbishment of all four Darlington reactors is estimated be about 123 m^3. It is estimated that a total of about 474 D-RWCs are needed for packaging this waste.

Figure 2-35: Retube Waste Container for Darlington Units 1 to 4

The D-RWC design utilizes a common RWC body with different cavity inserts for EF, PT/CT and CTI waste. The D-RWC is cylindrical in shape with an outer diameter of 1.9 m and an overall height of 2.4 m. The maximum weight of D-RWC in its heaviest configuration is 25,000 kg. The D-RWC is designed to be DGR-ready.

With the addition of a transport lid and impact limiters as shown in Figure 2-36, the D-RWC is designed to be transportable as a Type B packaging. In the Type B configuration, the D-RWC mimics the Trillium cask described in Section 2.3.2.3. The dimensions of the D-RWC in the Type B configuration are 2.59 m OD x 3.30 m OH.

Figure 2-36: Transport Packaging for Darlington Units 1 to 4 Retube Waste Containers

The refurbishment of the Darlington units has not yet begun and the total decay time for the last D-RWC is not currently known (although it will be at least 25 years). Given this, it is assumed that all the D-RWCs for all four units are shipped in their Type B configuration for purposes of this estimate.

The total number of shipments to transport the Darlington RWCs is estimated to be 474 for all 2045 and 2055 transport distances.

2.4 Truck Transport Compliance

For purposes of this study, compliance with the Ministry of Transportation, Ontario (MTO) truck transport requirements[9] summarized in Table 2-1 is assumed for transportation packaging selection and truck transport operations. Optimal radioactive waste transportation packaging systems incorporate a balance between maximizing waste capacity, providing sufficient shielding to attenuate dose rates, and minimizing the number of transports, particularly those requiring special permitting. Larger capacity containers reduce the number of L&ILW shipments from the WWF to the alternate location but may be oversized and/or overweight in some configurations. A preference is given to maintaining the size and weight of transports within the MTO limits for compliant truck shipments not requiring a permit, similar to that shown in Figure 2-37.

Figure 2-37: OPG Legal Size and Weight Freight Container Truck Shipment

Figure 2-38: OPG Legal Size and Weight Trillium Flask Truck Shipment

Provincial and municipal permits for oversized and/or overweight truck shipments typically impose routing and time of day or year restrictions, e.g., spring thaw road restrictions from March through May, as indicated in Table 2-1. Such shipments would need to be planned and scheduled around such seasonal restrictions should they occur. These are generally accounted for in the estimate. For some transport packages, purpose built trailers may be needed to optimize axle weight distribution and total conveyance height and length such as that shown in Figure 2-38. The cost of such purpose built trailers is included in the estimate for waste categories that utilize an existing transport packaging design, e.g., the Trillium flask for resin liners. Conversely, for waste categories that require a custom transport packaging that has not yet been designed and that may be oversized and/or overweight, e.g., the Type B overpack for the Bruce RWCs, the need for such purpose built trailers has not been determined at this juncture. For such waste categories, standard transport conveyances are assumed for the estimate.

[9] Ministry of Transportation Ontario, Highway Traffic Act, Ontario Regulation 413/05, "Vehicle Weights and Dimensions – for Safe, Productive and Infrastructure Friendly Vehicles," November 29, 2016.

Table 2-1: Ministry of Transportation Ontario Truck Regulations Summary[10]

Parameter	Limiting Value
Width: ▪ Vehicle including load	 2.6 m
Length: ▪ Combined tractor & trailer	 23 m
Height: ▪ Vehicle including load	 4.15 m
Weight (< 7,500 kg front axle): ▪ 5 axles, ≥ 3.6 m spacing ▪ 6 axles, ≥ 3.6 m spacing ▪ 7 axles, ≥ 3.6 m spacing ▪ 8 axles, ≥ 3.6 m spacing	Legal GVW (tonnes) 39.4 to 45.5 41.7 to 54.5 54.4 to 61.7 56.8 to 63.5
Speed Restrictions: ▪ On bridge crossings	 > 45 tonnes
Permit Type (if required): ▪ Annual permit ▪ Oversized ▪ Overweight ▪ Processing time ▪ Permit fee	 12 month period 3.7m(W), 4.26m(H), 25m(L) up to 63.5 tonnes 10 to 15 days $440/yr.
Restrictions (if permitted load): ▪ Night moves ▪ Holiday moves ▪ Weekend moves ▪ Congested traffic ▪ Bonding ▪ Flags, signs & lighting ▪ Escort vehicle(s) ▪ Reduced load period ▪ Corridor moves ▪ Convoy moves ▪ Construction zones	 Allowed per restrictions Allowed per restrictions Allowed per restrictions Not in greater Toronto area Conditions not expected to warrant Only needed for oversized Only needed for oversized March, April, May Moves all within Ontario 10 km minimum spacing Only restricted for oversized

2.5 Truck Transport Fuel Consumption Estimate

Tractor/trailer road transport requiring more than 22,000 total shipments on public roads between the WWMF and the alternate location over a 30+ year period will generate emissions that need to be considered in environmental assessments. The total estimated fuel consumption associated with this truck transport campaign for both alternate location scenarios and the assumed 100 km and 300 km transport distances beginning in year 2045, and 200 km and 2,000 km transport distances beginning in year 2055 are provided in Table 2-2.

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[10] The summary information shown in this table is generalized for purposes of this study. Detailed requirements, including dimensional and weight limits for specific tractor/trailer combinations, are provided in the Highway Traffic Act Regulation 413/05 per the MTO.

Table 2-2: Estimated Truck Fuel Consumption

Parameter	Transport Package	
	≤ 60,000 lbs (≤ 27.2 Mt)	> 60,000 lbs (> 27.2 Mt)
Tractor/Trailer Type	Standard	Heavy-Haul
Number of Axles	5 or 6	7 or more
Typical Trailer Type	45 to 53 ft flatbed or drop-deck	55 ft or longer double-drop gooseneck
Escort Vehicle Required?	No if Legal Size	Yes if also Oversized
Restrictions	Compliant/Unrestricted if Legal Size	Permitted/Restricted/Seasonal
Truck Movement Rate	Assume 24 hrs./day	Assume 8 hrs./day average
Average Fuel Mileage with Load (km/liter)	9.7	8.1
Average Fuel Mileage Empty (km/liter)	11.3	11.3
Percentage of Trips at Shipment Weight (2045)	89%	11%
Percentage of Trips at Shipment Weight (2055)	90%	10%
100 km Alternate Location Distance Beginning in Year 2045		
Number of Round Trips	10,147	1,191
Total Round Trip Distance (km)	2,029,315	238,200
Fuel Consumed with Load (liters)	105,037	14,795
Fuel Consumed Return Empty (liters)	90,032	10,568
Total Fuel Consumed (liters)	195,069	25,363
Cumulative Total Fuel Consumed (liters)		***220,432***
300 km Alternate Location Distance Beginning in Year 2045		
Number of Round Trips	10,147	1,191
Total Round Trip Distance (km)	6,087,945	714,600
Fuel Consumed with Load (liters)	315,111	44,385
Fuel Consumed Return Empty (liters)	270,095	31,704
Total Fuel Consumed (liters)	585,206	76,089
Cumulative Total Fuel Consumed (liters)		***661,295***

Table 2-2: Estimated Truck Fuel Consumption

Parameter	Transport Package	
	≤ 60,000 lbs (≤ 27.2 Mt)	> 60,000 lbs (> 27.2 Mt)
200 km Alternate Location Distance Beginning in Year 2055		
Number of Round Trips	10,801	1,191
Total Round Trip Distance (km)	4,320,570	476,400
Fuel Consumed with Load (liters)	223,632	29,590
Fuel Consumed Return Empty (liters)	191,685	21,136
Total Fuel Consumed (liters)	415,317	50,726
Cumulative Total Fuel Consumed (liters)		***466,042***
2,000 km Alternate Location Distance Beginning in Year 2055		
Number of Round Trips	10,801	1,191
Total Round Trip Distance (km)	43,205,700	4,764,000
Fuel Consumed with Load (liters)	2,236,320	295,901
Fuel Consumed Return Empty (liters)	1,916,846	211,358
Total Fuel Consumed (liters)	4,153,165	507,258
Cumulative Total Fuel Consumed (liters)		***4,660,424***

2.6 Transportation Risk Assessment

This section of the study provides a preliminary assessment of the incremental radiological and conventional risks that are inherent to a large long-duration transportation campaign by truck on public roads, such as that to package, transport and off-load the entire inventory of L&ILW from the WWMF to an alternate location. For the DGR Project at the Bruce Nuclear site, these incremental risks are avoided since transportation outside the OPG controlled area on public roads is not required.

The radiological risk assessment performed for this study is primarily based on supporting information obtained from nuclear industry organizations worldwide, including that published electronically or in print by the International Atomic Energy Agency (IAEA) the world's center of cooperation for things nuclear[11], the World Nuclear Association an international industry trade group, the U.S. Department of Energy a governmental entity[12], and the Society for Plant and Reactor Safety (Gesellschaft für Anlagen-und Reaktorsicherheit-GRS) gGmbH an independent non-profit research organization supporting the German government[13]. Similarly, the assessment of conventional risks is supported by data from the Ministry of Transportation Ontario and other transportation agencies.

Radioactive material is not unique to nuclear power generation and only about 5% of such transports are nuclear fuel-cycle related[14]. Radioactive materials are utilized extensively worldwide in a wide range of applications including medicine, research, defense, manufacturing, agriculture, non-destructive testing and minerals' exploration. Industry data[15] shows that about 20 million packages of all sizes containing nuclear materials, which includes radioactive waste similar to that residing at the WWMF, are transported around the world on a regular basis via public roads, railways, waterways and even by air.

Around the world, the materials with intermediate to high radionuclide activity levels that pose the greatest hazard are shipped using robust and secure packagings in accordance with international regulations[16], the same regulations that underpin those established by the CNSC to govern such transports in Canada, as described in Section 2.2. This body of transportation regulations is relatively universal, mature and administered on a continuous basis by the competent regulatory authority for each nation state, e.g., the CNSC in Canada, consistent with

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[11] IAEA-TECDOC-1346, *"Input Data for Quantifying Risks Associated with the Transport of Radioactive Material"*, International Atomic Energy Agency (IAEA), March 2003

[12] DOE/EM/NTP/HB-01, *"A Resource Handbook on DOE Transportation Risk Assessment"*, U.S. Department of Energy, Office of Environmental Management, National Transportation Program, July 2002

[13] Gesellschaft für Anlagen-und Reaktorsicherheit (GRS) gGmbH website page for Transport Studies, https://www.grs.de/en/content/2009-konrad-transport-study

[14] World Nuclear Transport Institute website, "Nuclear Transport Facts", http://www.wnti.co.uk/nuclear-transport-facts/nuclear-transport-facts.aspx

[15] World Nuclear Association website, *"Transport of Radioactive Materials"*, http://www.world-nuclear.org/information-library/nuclear-fuel-cycle/transport-of-nuclear-materials/transport-of-radioactive-materials.aspx

[16] IAEA SSR-6, "Regulations for the Safe Transport of Radioactive Material," International Atomic Energy Agency (IAEA), 2012

international norms. The effectiveness of this regulatory framework and the implementing policies and practices utilized by industry worldwide to mitigate the risk of radioactive material transports is evidenced by historical data. Such data shows that whilst there have been transportation related accidents over the past 40+ years, there has never been one in which a transport package with highly radioactive material has been breached, or has leaked.

There are comparable examples for the planned transport of L&ILW from nuclear facilities to a DGR for emplacement internationally. Most notably the Konrad repository for L&ILW located in central Germany has been approved by the Federal Office for Radiation Protection (BfS) and granted a license by Federal Office for the Regulation of Nuclear Waste Management (BfE) in 2002 for the 303,000 m^3 of L&ILW that is projected by year 2080[17]. The Konrad repository is currently under construction which is planned for completion in the 2019 timeframe with commissioning for operation planned thereafter.

The BfS's plan calls for transporting 110,000 m^3 of existing L&ILW to the Konrad repository in the first 10 years of waste acceptance, 41% of which emanates from nuclear power generation, and 56% of which emanates from other sources. For the reference scenario, the majority of this waste is planned to be transported by rail, with the remaining 20% transported by truck. This includes transporting 2,300 transport packages per year averaging 50 packages per week. To facilitate the planned transports, the GRS undertook a comprehensive study in 2009 that was commissioned by the Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (BMUB) to examine and assess the possible radiological effects of shipments of radioactive waste to the Konrad repository. The study concludes that the planned shipments will not result in any undue radiological risk to the affected population or the environment.[18]

The transportation of radioactive materials poses both radiological and conventional risks, including risks to both crew members and members of the public. The transportation of radioactive materials poses radiological risks because of the characteristics and potential hazards of the material being transported. Conventional risks include those resulting from the nature of transportation itself, independent of the radioactive characteristics of the cargo. For instance, increased levels of pollution from vehicular emissions (e.g., fugitive dust and engine exhaust) occur. Similarly, traffic accidents during transportation may cause injuries and fatalities.

The incremental radiological and conventional risks associated with the transport of L&ILW from the WWMF to an alternate location as described in this report include those associated with the following operations:

- Waste and/or container packaging for transportation and transport conveyance loading activities performed at the WWMF.
- Truck transportation operations on public roads along designated transportation corridors to the alternate location.
- Transportation package off-loading activities performed at the alternate location.

[17] German Federal Office for Radiation Protection (Bundesamt für Strahlenschutz-BfS) website page for the Konrad repository, http://www.endlager-konrad.de/Konrad/EN/themen/endlager/endlager_node.html

[18] Gesellschaft für Anlagen-und Reaktorsicherheit (GRS) gGmbH website for the 2009 Konrad Transport Study, https://www.grs.de/en/content/2009-konrad-transport-study

The risks associated with operations performed on OPG controlled sites are managed under OPG's health and safety and radiological control programs. The radiological and conventional risks associated with truck transportation on public roads outside OPG controlled sites are described and assessed further in this report section.

2.6.1 *Radiological Risks*

For radioactive materials such as the L&ILW at the WWMF, the radiological risks of primary concern during packaging, road transportation and off-loading at the alternate location are exposure to low levels of ionizing radiation. The radiological risk of truck transport on public roads includes exposures to radiation that may occur during routine (i.e., incident-free), normal (i.e., minor mishaps), and accident (e.g., a major event), conditions of transport, as defined by the CNSC transportation regulations described in Section 2.2. During such conditions of transport, the external radiation field of the transport package is kept below the limits specified by these regulations to effectively mitigate these radiological risks. During a transportation-related accident, the risk of increased radiation levels depends on the activity level of the radioactive material being transported, the severity of the accident and the performance of the primary safety features of the packaging, (i.e., the radiation shielding and containment boundary).

Although highly improbable given the rigorous packaging standards and practices employed for the transport of radioactive materials, extremely severe accidents, (e.g., a high velocity impact with a massive rigid surface or projectile commensurate with an engulfing sustained hydrocarbon fire), pose the greatest risk for the release and dispersal of some radioactive material. However, decades of operational experience and package testing have shown that the rigor of the transport packaging regulations which, as described in Section 2.2, are commensurate with the radioactive material's activity level and exposure risk, have been highly effective in preventing increased radiation exposures following accidents. The potential exposures, (i.e., radiation dose), to the affected population from transporting radioactive materials has historically been very low, whether during routine, normal or accident conditions of transport.

The incremental radiological risks for transporting the L&ILW from the WWMF to an alternate location can be grouped by operational activity as follows:

- The activities necessary for waste and/or container packaging for transportation and transport conveyance loading performed at the WWMF, considering the number of workers involved, protective equipment used, and the operations performed during lifting/handling, loading, and movement of materials within the facility.
- The activities necessary for truck transport on public roads from the WWMF origin to the alternate location destination considering the number of shipments and the logistics for the transport. The associated radiological risks include the exposure to radiation and the resultant health effects to the affected population of persons in proximity to the transportation package, including crew members and members of the public. Members of the public to consider include persons along the predetermined transport corridor (pedestrians or persons living or working in proximity to the route), sharing the route (persons traveling on the same route), and at stops (e.g., persons at rest areas or refueling areas).
- The activities necessary to perform the off-loading operations at the alternate location which are similar to those performed on the front-end at the WWMF. The return shipment of empty

reusable transport packagings and truck tractor/trailers to the WWMF to repeat the cycle until all the L&ILW is removed from the WWMF also poses risks, both radiological and conventional.

The OPG design standards, procedures and controls invoked at the WWMF and alternate location would effectively mitigate the incremental radiological risks associated with the activities performed on the OPG controlled sites. Compliance with the rigorous transportation packaging standards described in Section 2.2, in combination with planning, logistics, training, operational controls and regulatory compliance would be employed to mitigate the incremental radiological risks associated with truck transport on public roads, including the active engagement of provincial and local governments and stakeholders.

As described above, the extent of radiation exposure to affected persons under accident conditions at any point along the transport route depends on the activity level of the waste, the severity of the accident and the performance of the transport packaging's safety features. Under accident conditions, implementation of emergency response planning and deployment of first responders along the transport route that are trained and equipped to mitigate the effects of an accident, whether minor, major or severe would be utilized. Other mitigating preparations that would better enable the affected jurisdictions along the transport route would include periodic drills, simulations, communication protocols and shipment tracking systems, consistent with current practices for radioactive material transports.

2.6.1.1 Routine and Normal Conditions of Transport

The radiological risk associated with routine and normal transports of radioactive material such as L&ILW includes the potential exposure of affected persons to low-level external ionizing radiation. For routine and normal transport conditions, the major groups of potentially exposed persons include the following members of the affected population:

- *Persons Along the Route:* People living or working on each side of the transportation corridor.
- *Persons Sharing the Route:* People in vehicles sharing the transportation corridor. This group includes persons traveling in the same or the opposite direction as the shipment, as well as persons in vehicles passing the shipment.
- *Persons at Stops:* People nearby while a shipment is stopped on route, including stops for refueling, food, and rest.
- *Crew Members:* Truck transportation crew members.
- *Person in Traffic Obstruction:* A person or persons stopped next to a radioactive material shipment (e.g., because of a traffic slowdown).
- *Person at Truck Service Station:* A person or persons that work at a service station utilized for truck maintenance or repairs while on route.

The U.S. Department of Energy (DOE) has published historical radiation exposure data for the truck transport of radioactive materials as part of the environmental assessments performed for their nuclear facilities[19]. The DOE data shows that the aggregate cumulative radiation dose to population of affected persons including crew members and members of the public for comparable L&ILW shipments is less than 1.0E-04 person-rem per kilometer traveled for normal conditions of transport by truck[20]. Utilizing this DOE data and the estimated total distances traveled over the 30 year period of truck transport operations for the two alternate location scenarios shown in Table 2-2, the collective annual dose to the entire population of affected persons along the transport corridor, (including those in the population groups described above), are estimated. The resulting estimated total annual incremental radiation doses to the entire population for normal conditions of transport are shown in Table 2-3.

In order to estimate the incremental radiation dose to an individual, the number of persons in the affected population, including crew members and members of the public is needed. In general, the size of the affected population along the transport corridor can be expected to increase with increasing transport distance. For purposes of this study, it assumed that there are two affected persons per kilometer of distance by road from the WWMF to the alternate location. The resulting estimated annual radiation dose to an affected individual for normal conditions of transport is shown in Table 2-3.

Table 2-3: Estimated Incremental Annual Radiation Dose to Affected Population for Truck Transport to Alternate Location

DGR Host Geology	DGR Availability (year)	One-Way Distance by Road (km)	Total Number of Road Shipments	Total Road Distance Traveled (km)	Aggregate Collective Dose Rate Based on U.S. DOE Data		Transport Project Duration (years)	Estimated Annual Radiation Dose to Affected Population Along Transport Corridor				
								Entire Population		An Individual		
										Assumed # Persons per km of Distance:		2
					(person-rem/km)	(person-mSv/km)		(person-rem/y)	(person-mSv/y)	Assumed # of Affected Persons	(rem/y)	(mSv/y)
Sedimentary	2045	100	22,675	2,267,515	1.0E-04	1.0E-03	30	8	76	200	0.04	0.4
Sedimentary	2045	300	22,675	6,802,545	1.0E-04	1.0E-03	30	23	227	600	0.04	0.4
Crystalline	2055	200	23,985	4,796,970	1.0E-04	1.0E-03	30	16	160	400	0.04	0.4
Crystalline	2055	2,000	23,985	47,969,700	1.0E-04	1.0E-03	30	160	1,599	4,000	0.04	0.4

The estimated annual radiation doses shown in Table 2-3 indicate that whilst some incremental dose can be expected as a result of truck transports of L&ILW from the WWMF to the alternate location, the incremental dose to an individual in the affected population would be very low, well below the 1 mSV annual exposure limit to a member of the public set by the CNSC regulations. The assessment also shows that the incremental annual dose to an individual is also well below that due to natural background radiation throughout Canada[21].

[19] DOE/EM/NTP/HB-01, *"A Resource Handbook on DOE Transportation Risk Assessment",* data shown in Figure 4.2 for DOE facilities transporting comparable L&ILW and/or radioactive materials by truck, U.S. Department of Energy, Office of Environmental Management, National Transportation Program, July 2002

[20] Like the transport packages identified for the alternate location transports described in Section 2.3, the external dose rates for the transport packages used for these DOE transports were below the regulatory limits described in Section 2.2.

[21] Canadian Nuclear Safety Commission (CNSC), radiation dose data published on CNSC website, http://nuclearsafety.gc.ca/eng/resources/radiation/introduction-to-radiation/radiation-doses.cfm

To benchmark this estimate, comparisons can be made with the radiation exposures estimated for transporting L&ILW to the Konrad repository in Germany described earlier in this report section. The analysis performed as part of the Konrad transportation study calculated the maximum annual radiation exposure for multiple transport mode scenarios, including 100% rail shipments, 100% truck shipments and 80% rail plus 20% truck shipments, the latter of which is the reference scenario. The analysis for the 100% truck shipment scenario determined the maximum annual radiation exposure to members of the public to be 0.025 mSV per year for normal conditions of transport. This 100% truck shipment scenario assumed 25 to 50 transports per week with the affected persons assumed to be outdoors at an average distance of 5 meters from the transport packages. The same analysis determined the maximum annual radiation exposure to the affected crew members to be less than 1.1 mSV per year for normal conditions of transport. The affected persons included those in sustained proximity to the transport packages such as the truck drivers. The study concludes that these annual exposure levels are well below those due to natural background radiation in Germany which averages 2.1 mSV per person per year[22]. Based on the results of the Konrad study analysis which is much more rigorous than the preliminary assessment performed for this study, the estimated incremental annual radiation doses shown in Table 2-3 for truck transports of L&ILW from the WWMF to the alternate location are considered conservative and bounding.

2.6.1.2 Hypothetical Accident Conditions

In addition to the routine and normal condition radiological risk described in Section 2.6.1.1, the incremental radiological risk to the population along the transport corridor also includes that related to the potential for accidents due to whatever unavoidable cause, considering the large number of transports on public roads over a long period of time that are required. The range of hypothetical accidents to consider include higher probability accidents with low consequences (no risk of increased radiation exposure), and lower probability accidents with high consequences (possible risk of increased radiation exposure).

To assess the radiological dose risks for accidents postulated to occur during such a transport campaign, the range of hypothetical accident scenarios to consider include:

1. Minor accidents in which there is no breach of the packaging’s containment boundary and no loss of shielding effectiveness.
2. Major accidents in which there is no breach of the packaging’s containment boundary but there is some loss of shielding effectiveness caused by displacement of the packaging’s shielding material.
3. Severe accidents with the potential for some release and dispersal of radioactive material caused by leakage of the packaging’s containment boundary.

As Table 4-6 indicates, of the total volume of L&ILW transported to the alternate location, 93% is LLW and only 7% is ILW. Similarly, of the total number of shipments of L&ILW to the alternate location, 67% are LLW shipments and 33% are ILW shipments. As described in Section 2.2, the transport packaging required by the regulations for lower activity waste is less

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[22] Gesellschaft für Anlagen-und Reaktorsicherheit (GRS) gGmbH website for the 2009 Konrad Transport Study, https://www.grs.de/en/content/2009-konrad-transport-study

robust, (but still of high integrity), compared with that required for higher activity waste commensurate with the radiological risk posed by exposure to the packaging's contents. The application of these regulatory principles to the transport packaging types utilized effectively mitigates the radiological risk of transport accidents for the shipment of the L&ILW to the alternate location as follows:

- *LLW Shipments:* Of the transport packagings utilized for the shipment of LLW to the alternate location for purposes of this study, 90% are Type IP-2 packagings and 10% are Type A packagings, neither of which are required to fully maintain their capability to withstand transportation accidents per the regulations. Compliance with these transport regulations mitigates the radiological risk of accidents for the shipment of LLW by requiring that the unshielded dose rate of the waste contents be maintained at acceptably low levels without taking credit for the transport packaging. So while the risk of a release or dispersal of LLW from the packaging due to a major or severe transport accident is higher compared with that for higher activity waste, the resulting risk of increased radiation exposure to LLW is mitigated per the regulations by limiting the permissible activity level of the waste contents. As indicated above, the majority of shipments to the alternate location are LLW transports.
- *ILW Shipments:* Of the transport packagings utilized for the shipment of ILW to the alternate location, 70% are Type B packagings which are required to fully maintain their capability to withstand transportation accidents, and 30% are Type A packagings which are not. The Type B packagings contain ILW with higher radionuclide quantities that require shielded packagings with a robust containment boundary to meet the stringent radiation dose limits and prevent a release of radioactive material during an accident. The Type A packagings contain ILW with lower radionuclide quantities that have an acceptably low unshielded dose rate without taking credit for the transport packaging, similar to that for LLW described above. So not only is the risk of a release or dispersal of higher activity ILW from a Type B packaging due to a major or severe transport accident lower compared with that of lower activity waste packagings, the risk of increased radiation exposure to ILW is mitigated per the regulations by utilizing a more robust shielded packaging. As indicated above, a minority of shipments to the alternate location are LLW transports.

As noted earlier in this report section, over the past 40+ years the evolution of the transport regulations which require a high performance transportation packaging for the shipment radioactive materials with intermediate to high activity levels have been highly effective at preventing a release or dispersal of radioactive material following accidents. In addition, the comprehensive planning, preparations and controls that are employed during such transports have been effective at mitigating the consequences of accidents the relatively few times that they have occurred. Based on this historical evidence and the mitigating actions described above, it can be asserted that the risk of increased radiation exposures due to an accident during the transport of L&ILW to the alternate location that exceed those estimated for the normal conditions of transport in Section 2.6.1.1 is very low. As indicated above, whilst the risk of a release or dispersal of radioactive material due to a major or severe accident during the transport of LLW and lower activity ILW to the alternate location is considered an unlikely but credible event, the risk of increased radiation exposure is mitigated by limiting the activity of the waste contents per the regulations. Further, it can be asserted that the risk of a release or dispersal of highly radioactive material due to a severe accident during the transport of higher activity ILW to the alternate location whilst conceivable is not considered a credible event since the probability of occurrence of such a causal severe accident is less than one in a million per year[23], (an accepted threshold for risk-informed regulatory reviews).

These conclusions are substantiated by those made by the GRS based on its analysis of hypothetical accidents of varying severity postulated to occur during the transport of L&ILW to the Konrad repository. In order to assess the radiological risk of such accidents, the GRS carried out a comprehensive probabilistic transport accident analysis. The key parameters for the analysis to determine the level of risk for the release and dispersion of radioactive materials included the frequency and severity of accidents (as measured by general transport accident statistics similar to those described in Section 2.6.2), the characteristics and behavior of the radioactive materials in the waste, and the performance of the transport packaging. The exposure risk for the entire population to both direct radiation and atmospheric dispersion within 25 km radius of the location of the postulated accident were evaluated. Nine accident scenario categories were simulated with a range of bounding impact velocity and concurrent fire assumptions. The following results and conclusions were derived from the simulation of the hypothetical severe accident scenarios postulated to occur during the transport of L&ILW to the Konrad repository:

- In the majority of accidents of sufficient severity to cause even a fractional release, the predicted effective doses are far below those of the annual natural radiation exposure levels, even without taking mitigating actions, such as evacuating persons in close proximity and instructing people in the area to remain indoors.
- A transport accident with sufficient severity to cause even a fractional release and dispersion of radioactive material is predicted to occur once in 260 years. The associated effective dose is less than 0.3 mSv in 99 of 100 cases.
- On statistical average, a maximum dose of 8 mSv to an affected individual due to a severe accident that causes a release and dispersion of radioactive material is only predicted to occur once in 10 million years.
- Even for the worst case severe accident predicted to occur once in 10 million years, and even at close proximity of 150 meters or less, the maximum dose to an affected individual is well below 50 mSV.

2.6.2 *Incremental Conventional Risks*

The transportation of the L&ILW from the WWMF to the alternate location by truck on public roads also poses incremental risks by conventional causes. These risks are independent of the radioactive nature of the cargo and would be incurred with similar shipments of any commodity. The incremental conventional risks include both incident-free and accident related transportation risks to crew members and members of the public which are summarized as follows:

[23] *"Radioactive Materials Transport Accident Analysis"*, data for accident severity probabilities and consequences, T. I. McSweeney, et. al, U.S. Battelle Memorial Institute, 2004.

1. There are conventional safety risks associated with performing the following activities to facilitate the transporting the L&ILW to the alternate location for the entire evolution of the project:

    - The supply and delivery of materials including a large number of new transportable containers from manufacturing facilities to the WWMF by commercial truck transport via public roads.
    - The deployment of heavy equipment and truck tractor/trailers to and from the WWMF and alternate location via public roads.
    - The utilization of such heavy equipment and truck tractor/trailers at the WWMF and alternate location for lifting, handling, loading, conveying and off-loading the waste containers, large components and repackaging of bulk waste as needed to and from the transport packagings and truck conveyances to facilitate transport operations.
    - The deployment of workers and the other goods needed to resource the L&ILW transportation project via public roads.

2. There are conventional health risks associated with road transportation resulting from transport vehicles that generate air pollutants during operation, independent of the nature of the shipment. Such risks include the effect of fugitive dust, sulfur dioxide and particulate emissions from truck operations and diesel exhaust. The assessment of environmental effects including the vehicle emissions associated with transport to the alternate location are addressed in a separate technical document, as described in Section 1.0.

3. Conventional risks also include the potential for transportation-related accidents that result in injuries or fatalities due to physical trauma unrelated to the cargo being shipped, as described below. Such risks include fatalities from mechanical and other causes. Round-trip shipments that include the return trip to the origin site with or without a cargo, e.g., empty reusable transport packagings and truck tractor/trailers, pose an added accident risk.

The MTO monitors road safety in the province of Ontario and publishes an annual report with accident data and statistics, including those for large trucks[24]. This data indicates that a total of 15,692 collisions involving large trucks occurred in the province of Ontario in 2013. Of these, 13,022 resulted in property damage, 2,577 resulted in personal injuries, and 93 resulted in one or more fatalities. Although the number of fatalities involving truck accidents is trending downward year-over-year in Ontario, historical data indicates the following[25]:

- Heavy truck crashes account for almost one-fifth of all motor vehicle fatalities and 5% of all the injuries.
- The per-vehicle fatality and injury rates for heavy trucks are much higher than those for all other types of vehicles.
- Heavy trucks have higher per-distance rates of fatal crashes but lower rates of injury crashes compared with all other types of vehicles.

[24] "Ontario Road Safety Annual Report 2013", Ministry of Transportation Ontario, Road Safety Research Office.

[25] "Heavy Trucks and Road Crashes", Traffic Injury Research Foundation, Ottawa Ontario, March 2004.

- Most of the fatalities and injuries in collisions involving heavy trucks were among people other than the truck occupants.
- The number of trucks on public roads in Canada is increasing year-over-year consistent with growth in the truck transport of goods.

The above assessment of conventional safety risks associated with trucking accidents is consistent with other data for truck transports, such as that maintained by the U.S. Department of Transportation which indicates the following trends[26]:

- The number of fatal trucks crashes is trending downward year-over-year.
- The number of injury truck crashes is also trending downward year-over-year.
- The number of vehicle miles traveled by large trucks is increasing year-over-year.

These incremental conventional risks to the health and safety of workers and members of the public described above are relevant to the packaging and truck transport of the L&ILW from the WWMF and off-loading at the alternate location.

2.6.3 *Incremental Risk Assessment Conclusions*

Based on the preliminary assessment of the incremental radiological and conventional risks associated with the packaging and road transport of the L&ILW from the WWMF and off-loading it at the alternate location described in Section 2.6.1 and Section 2.6.2, OPG considers the associated risks to the population of affected persons, including members of the public and crew members, to be limited and bounded. The associated profile of risks is considered to be determinate and quantifiable in terms of their probability of occurrence and their potential consequences. They can also be effectively managed and mitigated without undue risk to the affected population. The evaluation of such risks can be underpinned by data based on 40+ years of safe radioactive material shipments worldwide, and even more data for commercial cargo shipments using heavy trucks.

[26] U.S. Department of Transportation, Federal Motor Carrier Safety Administration website page https://www.fmcsa.dot.gov/safety/data-and-statistics/large-truck-and-bus-crash-facts-2014.

3. Waste Category Estimate Development

To determine the total estimated incremental cost for transporting the entire inventory of L&ILW from the WWMF to an alternate location, the estimated cost for transport packaging, road transportation and off-loading each waste category described in Section 2 is developed. The associated waste categories are assumed to be sequentially packaged for transportation, transported on public roads and off-loaded in accordance with the L&ILW waste category retrieval plan described in Section 1.2 and the time intervals shown in Table 1-1. As described in Section 1.3 , the indicative cost estimate for each waste category is developed consistent with AACE International Class 5 cost estimating practices.

3.1 Estimate Framework

The high level process steps needed to package and transport each waste category are depicted in Figure 3-1 which provides a basic framework used for developing the cost estimate for this study. These basic process steps are the same for the 100 km and 300 km distances for initiation of transports in 2045, and the 200 km and 2,000 km distances for initiation of transports in 2055. The processes depicted are grouped by waste category retrieval, waste category packaging for transportation, (which is broken down into waste container and large component preparation processes and transport packaging processes), and waste category road transportation processes. The processes are further grouped by those that are considered incremental for transportation, and those that are not considered incremental since they would be need to be performed irrespective of the alternate location.

A fundamental assumption for development of the cost estimate is that the transportation of each waste category is to be sequenced and keep pace with the sequence and time intervals previously defined by OPG for the planned activities at the Bruce Nuclear site for the retrieval of waste in each category, as described in Section 1.2. In this manner, each waste category is assumed to be packaged for transport and transported by road to the alternate location and off-loaded at the same rate that it is retrieved from interim storage at the WWMF. To facilitate the determination of the average shipping rate needed to achieve this objective, normalized timeline schedules for transporting each waste category are developed for the 2045 alternate location availability scenario and the 2055 alternate location availability scenario, as shown in Figure 3-2 and Figure 3-3. The normalized timelines for both of these scenarios are essentially the same except that the quantity of waste packages and shipments are slightly higher for the 2055 scenario for some waste categories.

The schedules show the sequence of waste category transportation and the number of shipments for each waste category, with lower activity LLW transported first, followed by higher activity ILW to maximize the decay period and to minimize dose uptake. No attempt to optimize the shipping schedule independent of the planned waste retrieval schedule is made to preserve alignment. As an example, given the extended availability date of the alternate location DGR versus that of the DGR at the Bruce Nuclear site, earlier shipment of the RWC waste categories than those shown on the Figure 3-2 and Figure 3-3 schedules may be achievable because of the comparatively longer waste decay time prior to DGR availability. This would make the 3 to 4 year delay in RWC shipments shown in the alternate location schedules unnecessary; however, alignment with the normalized waste retrieval schedule for the planned activities at the Bruce Nuclear site is maintained in all cases for consistency.

To achieve the associated timeline objective, more than 22,000 total shipments at an average shipping rate of 2 (two) truck shipments per day over a 30+ year period are needed to package and transport the entire inventory of L&ILW from the WWMF to the alternate location. For purposes of waste category cost estimating, this aggregate daily shipping rate is assumed to hold constant across all waste categories. Since the planned waste retrieval schedule is assumed to be the same irrespective of transport distance, this same daily shipping rate is utilized to estimate the transportation costs for the 100 km and 300 km distances for initiation of transports in 2045, and the 200 km and 2,000 km distances for initiation of transports in 2055. Consequently the level of resources needed to perform road transports (tractor/trailer equipment sets, drivers, fuel, etc.) are increased as needed commensurate with the transport distance to achieve a shipping rate of two per day. Since the round trip turnaround time increases significantly with road transport distance, the availability of the same transport packagings and truck transport resources to conduct the “next” shipment is reduced considerably as the distance increases. As a result, the level of these packagings and resources per shipment needed to conduct the longer road transports is significantly higher compared with those needed for the shorter road transports.

Nominal round-trip turnaround times of 1, 1.5, 2 and 8 days per shipment are assumed for the 100, 200, 300 and 2,000 km transport distances for compliant/unrestricted legal size/weight truck shipments assuming 24 hr./day truck movement. These assumed turnaround times are increased by a factor of three for permitted/restricted oversized and/or overweight truck shipments to account for the associated cumulative restrictions imposed on such shipments assuming an average of 8 hr./day truck movement.

3.2 Basis of Waste Category Estimates

The basis for the estimated indicative cost to package and transport each waste category is provided in Table 3-1 through Table 3-12. These basis of estimate tables include the following:

- *Section A:* Data for the bulk waste category that is pertinent to transportation. This includes the general classification of the bulk waste (LLW or ILW), the total quantities of waste for the waste category, the radiological characteristics of the waste used to determine the regulatory packaging type required for transportation as described in Section 2.2, and the corresponding regulatory waste classification (LSA, SCO, Type A or Type B waste).
- *Section B:* Data for the waste containers and large components in interim storage at the WWMF that is pertinent to transportation. These are grouped by common characteristics of the waste container or component to be packaged for transportation. This includes physical characteristics of the waste containers and large components and the quantities of each. For large components that are segmented as described in Section 2.1, the physical characteristics shown are those for the component segments to be transported.
- *Section C:* Identifies the regulatory packaging type that is utilized for transportation based on the data shown in Sections A and B (Types IP-2, A or B as described in Section 2.2). The common characteristics of the transport packaging design are grouped by regulatory packaging type. For LLW, these include the characteristics for the Type IP-2 and Type A packaging designs utilized for estimating. For ILW, these include the characteristics for the Type A and Type B packaging designs utilized for estimating. These are used to determine the features of the associated packaging design and the quantities needed for each. To the maximum extent possible, a currently existing commercially available transport packaging is

utilized as described in Section 2.3. In cases where a suitable currently existing commercially available transport packaging is not available, the estimated cost to design modified or new custom waste category-specific packaging(s) is included.

In addition, Section C provides the waste category-specific estimated cost to supply the transport packagings, including the cost for procurement, materials, fabrication and delivery of the packagings in the quantities identified. The estimated cost for the packaging-specific equipment needed for each waste category packaging system to facilitate installation of the transport packaging and securing it on the truck transport conveyance is included. The cost of equipment that is common to all waste categories that is utilized at the WWMF for transport packaging and truck transport preparation operations, and at the alternate location for off-loading operations are included elsewhere at the total project cost level as described in Section 4. Such common site equipment includes that used for lifting and handling waste containers, large components and transport packagings on the respective site, e.g., a yard crane and forklift, and other ancillary equipment and tools. The labour resources and the associated estimated cost needed to perform operations on the respective sites is also included elsewhere at the total project cost level as described in Section 4 since these resources are common to all waste categories.

- *Section D:* Provides the basis of estimate for truck transportation of the transport packagings identified in Section C from the WWMF to the alternate location. The truck transport operations are grouped by the general tractor/trailer type used to conduct the road transports in compliance with the MTO regulations, including standard tractor/trailers used to conduct unrestricted legal size/weight truck shipments, and non-standard trucks with extended size and/or heavy-haul capability used to conduct restricted oversized and/or overweight truck shipments. The total number of shipments and the rate of shipments (as described in Section 3.1) are provided for both groups. The number of tractor/trailer sets, the number of days needed to complete the road transport operations for the waste category, and the estimated cost are provided for each of the four assumed alternate location transport distances.
- *Section E:* Summarizes the basic assumptions made to develop the cost estimate for packaging and transporting each waste category, consistent with the general planning assumptions described in Section 1.3 and elsewhere in this document. Supporting explanations and qualifiers for the estimate are identified, including what is included and not included. The assumptions common to all waste categories are provided in Table 3-13.
- *Section F:* Provides the summary waste-category specific costs for each waste category for each of the four assumed transport distances. The total cost to maintain the reusable transport packaging systems and packaging-specific equipment for each waste category are estimated. Maintenance costs are estimated at 5% of supply costs for Type IP-2 and Type A packagings systems, and at 10% of supply costs for Type B packagings systems. The maintenance cost for common site equipment is estimated at the total project cost level as described in Section 4.
- *Section F:* Adjustment factors are applied to the total waste category cost to account for a range of uncertainties and risks inherent in the waste category cost estimate, given the high level nature of this study and the broad range of technical, planning and cost estimating

assumptions made at this early conceptual stage as described throughout this report. Such uncertainties accounted for by the adjustment factor include the following:

1. Variability in the actual waste characteristics anticipated at the time of retrieval/shipment (both physical and radiological) since no differentiation is made within a waste category for waste packaging purposes. A wide variety of waste container types and interim storage methods are actually utilized at the WWMF, (both currently and historically) that are not specifically accounted for in the estimate, and the actual preparations required for bulk waste components and equipment, (both large and small), to render them transportable are conceptual.
2. Broad assumptions are made about the waste activity for the purpose of establishing the regulatory classification and the associated percentage of the transportation packagings assumed for each packaging type. Similarly, broad assumptions are made about transport package size and weights for the purpose of determining whether a truck shipment is legal size and weight or oversized and/or overweight.
3. Many of the waste categories require unique custom transport packagings that have not yet been designed.

Such risk factors accounted for by the adjustment factor include:

1. No specific transportation planning and logistics have been performed to underpin turnaround times which could impact the estimate basis.
2. Specific planning for truck transport operations have not been developed. Potential interruptions and delays in waste retrieval and packaging operations, truck transports and turnaround times due to extreme weather, equipment breakdowns, lower than anticipated workforce productivity, etc. could impact the estimate basis.

All of these factors affect transport packaging approaches, transport packaging and tractor/trailer fleet sizes, and truck transport costs that are not specifically estimated and are accounted for by the adjustment factors given the high level conceptual nature of this study. The level of uncertainties and risks also increase the longer the transport distance which is reflected in the adjustment factor used.

The estimates for each waste category presented in this section are used to develop the combined total project cost estimate described in Section 4.

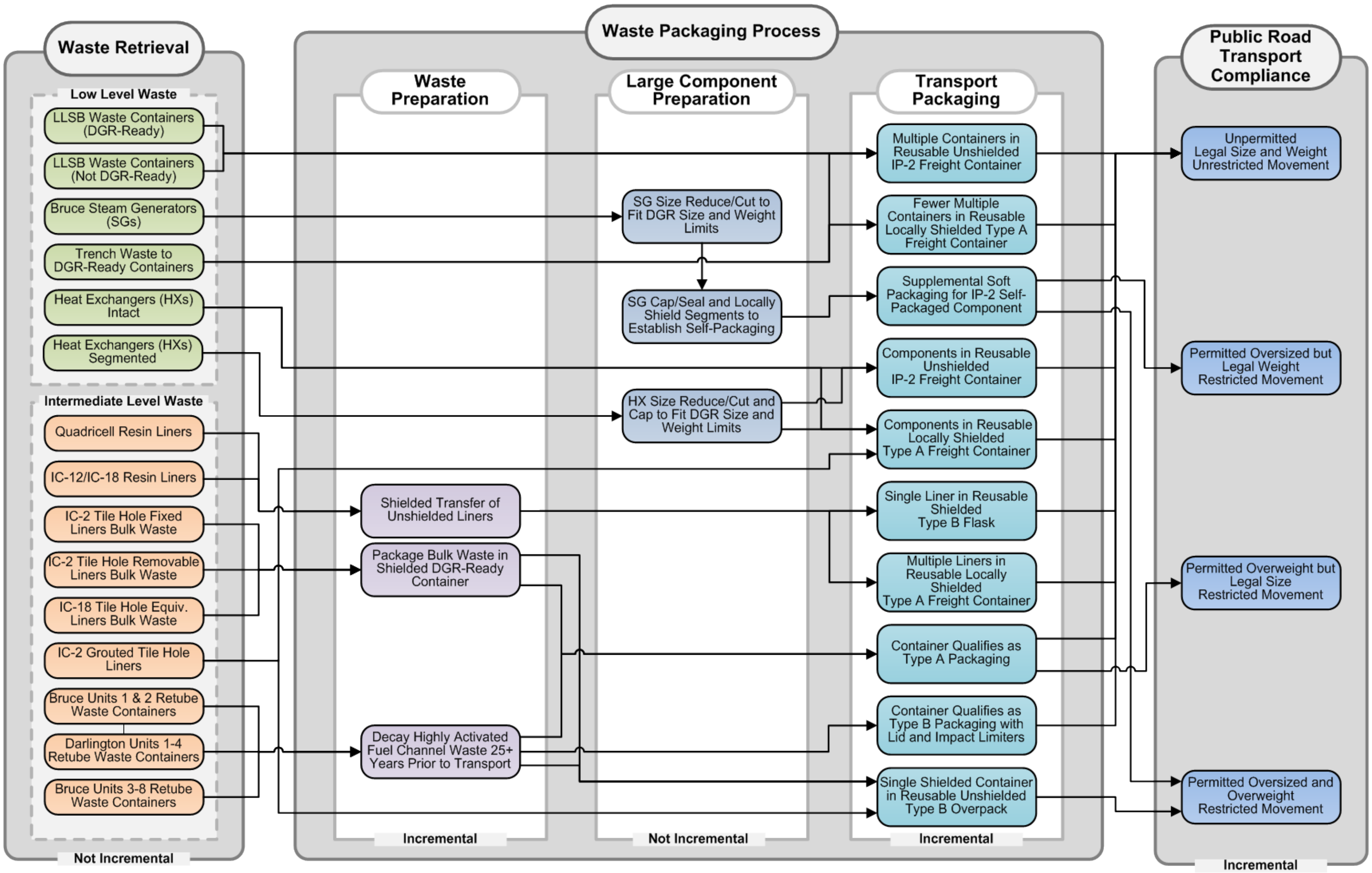


Figure 3-1: Waste Category Packaging and Transport Processes Utilized for Estimating

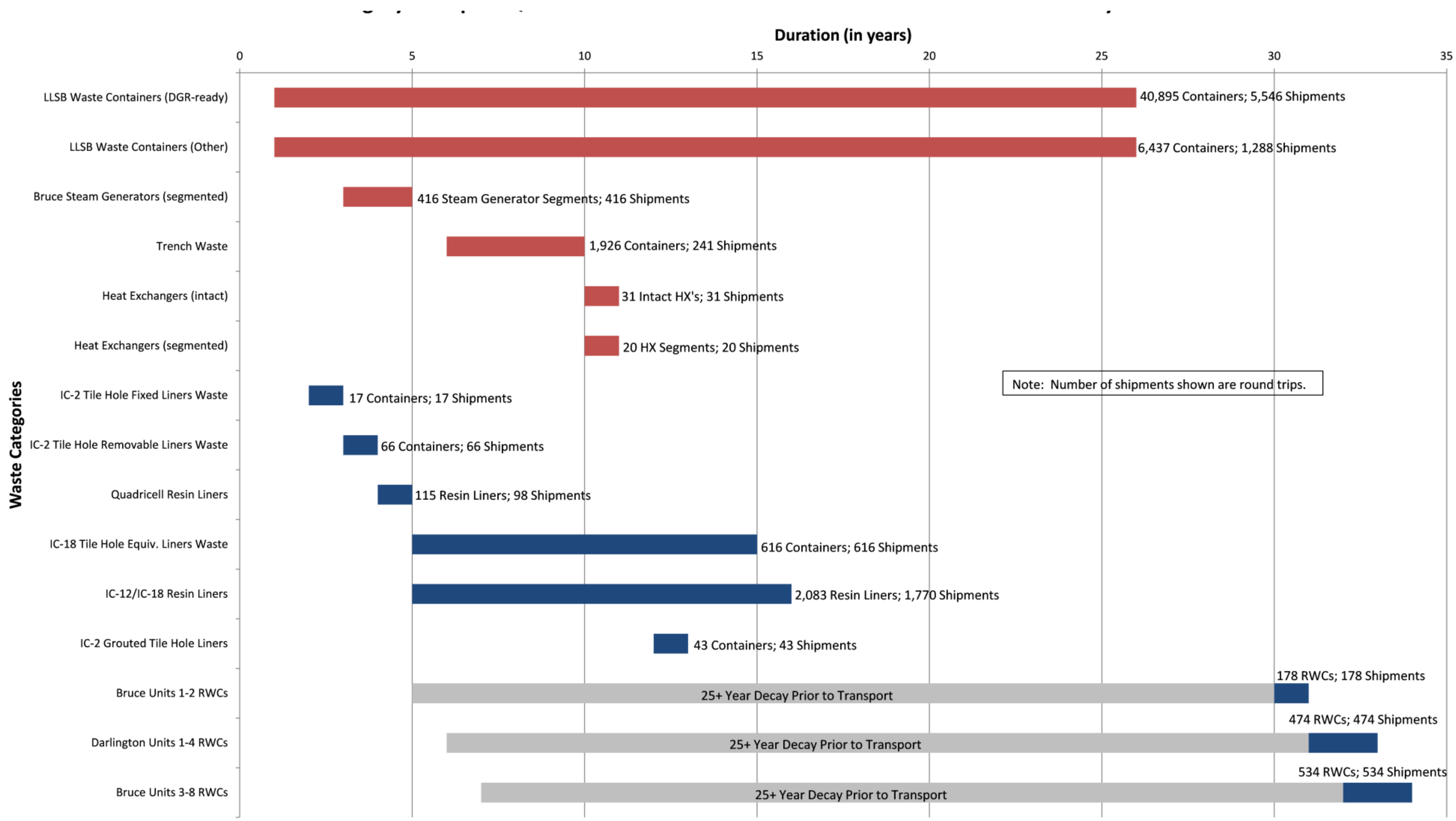


Figure 3-2: Waste Category Transport Quantities and Durations for Alternate Location DGR Availability in 2045

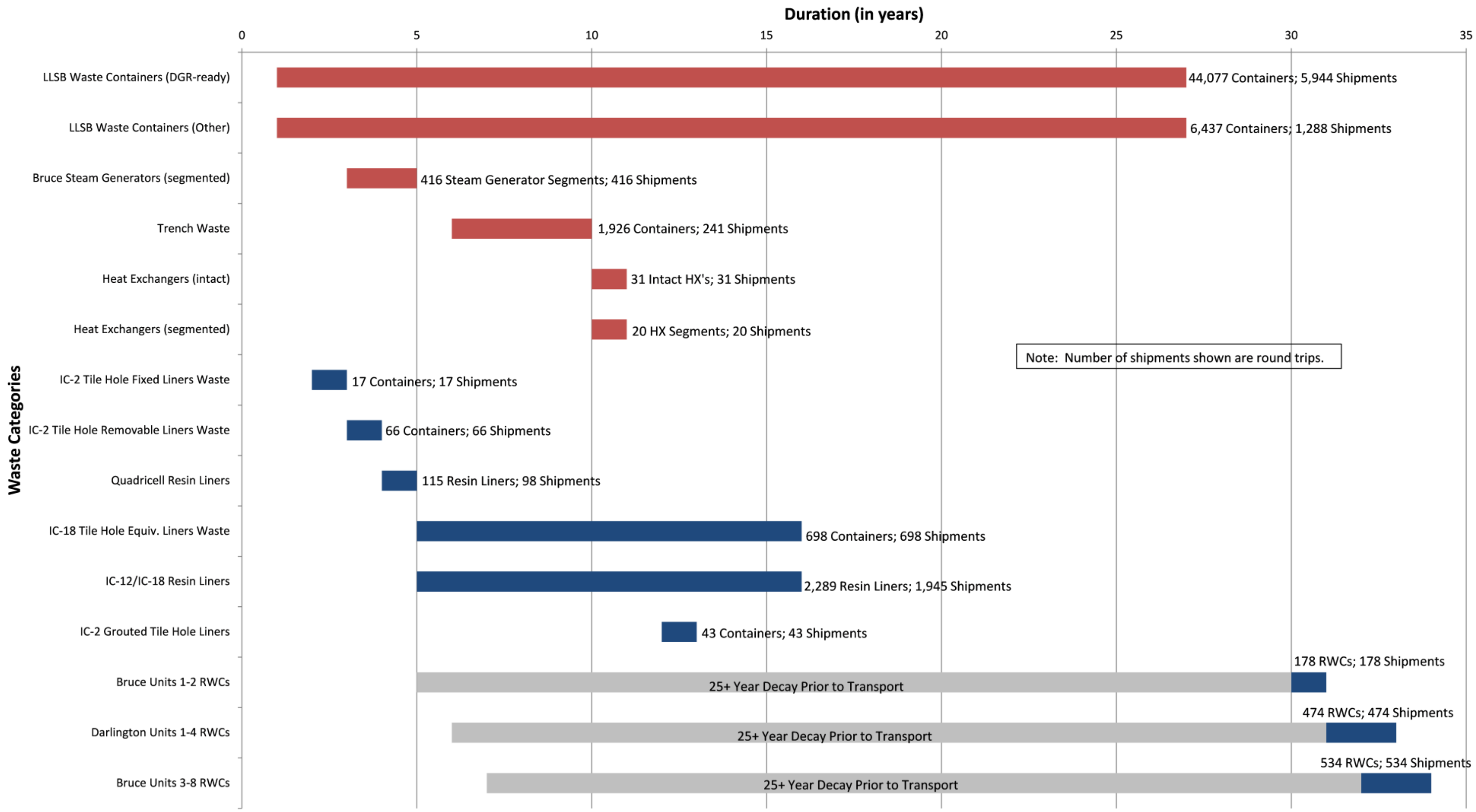


Figure 3-3: Waste Category Transport Quantities and Durations for Alternate Location DGR Availability in 2055

Table 3-1: Basis of Estimate for Packaging and Transporting LLSB Waste Category

Section A: Bulk Waste Category Data			
1	Class (LLW or ILW)	LLW	
2	Type	Non-Processible	
3	Physical Form	Paper, plastics, metal, etc.	
4	Total Volume (m^3) (2045, 2055)	126,889	134,844
5	Total Mass (kg) (2045, 2055)	4.75E+07	5.10E+07
6	Est. Total Activity (Bq)	3.81E+15	4.05E+15
7	Est. Specific Activity (Bq/m^3)	3.00E+10	
8	Est. Unshielded Dose Rate (mSv/hr)	99.8% < 10 & 0.2% > 10	
9	Waste Class (LSA-II, SCO-II, A, B)	90% LSA-II and 10% A	

Section B: Waste Container(s) or Large Component Data					
1	Waste Container/Comp. Grouping	1		2	
2	Type/Model	Non-Pro NPB47		4-High Non-Pro NPB4	
3	General Descriptor	Stackable Box		Stackable Bin	
4	Outside Dimensions (LxWxH, m)	1.96 x 1.32 x 1.19		2.3 x 1.2. x 1.5	
5	External/Gross Volume (m^3)	3.2		4.2	
6	Max. Gross Weight (kg)	1,460		1,066	
7	Handling Method(s)	Pallet Truck, Forklift, Crane		Pallet Truck, Forklift, Crane	
8	DGR Emplacement Ready?	Yes		Yes=5,790, No=6,437	
9	Quantity (2045 & 2055)	35,105	38,287	12,227	12,227

Section C: Transport Packaging & Equipment Estimate Inputs			
1	Transport Package Grouping	1	2
2	Transport Package Type (IP-2, A, B)	Type IP-2	Type A
3	Packaging Model/Descriptor	40 & 48 ft. Freight Containers	
4	Qty. Waste Cont./Comp. per Package	8 for NPB47, 5 for NPB4	
5	Standard, Custom or Self Packaging?	Standard	Mod Standard
6	Shielded or Unshielded Packaging?	Unshielded	Shielded
7	Reusable or One-Time Packaging?	Reusable	Reusable
8	New or Existing Packaging Design?	Existing	Mod Existing
9	Packaging Design and/or Licensing Cost	$60,000	
10	Packaging-Specific Equipment Cost	$112,000	
11	Transport Packaging Cost 100 km	$974,384	
12	Transport Packaging Cost 300 km	$1,948,768	
13	Transport Packaging Cost 200 km	$1,461,576	
14	Transport Packaging Cost 2,000 km	$7,795,072	

Section D: Road Transport Operations Estimate Inputs					
1	Shipment Grouping	1 (Type IP-2)		2 (Type A)	
2	Number of Shipments (2045 & 2055)	6,150	6,508	683	723
3	Rate of Shipments (#/day)	2		2	
4	Gross Transport Package Weight	< 40,000 lbs.	(< 18.1 Mt)	< 50,000 lbs.	(< 22.7 Mt)
5	Legal Size or Oversized Shipment?	Legal Size	(< 2.6m wide)	Legal Size	(< 2.6m wide)
6	Legal Weight or Overweight Shipment?	Legal Weight	(< 42.2 Mt)	Legal Weight	(< 42.2 Mt)
7	Standard, Extended or Heavy Trailer?	Standard		Standard	
8	Oversized Escort Required?	No		No	
9	Geology/Year DGR Available	Sedimentary 2045		Crystalline 2055	
10	One-Way Shipping Distance (km)	100	300	200	2,000
11	Est. Round Trip Duration (days)	1	2	1.5	8
12	Qty. Transport Packagings Needed	4	8	6	32
13	Qty. Tractor/Trailer Equipment Sets	2	4	3	16
14	Est. Road Transport Trucking Cost	$13,216,037	$39,648,112	$ 27,970,572	$279,705,717

Section E: Estimate Assumptions, Explanations & Qualifiers	
1	See Table 3-13 for common assumptions.
	Assumptions 1, 2, 3, 4, 5, 6, & 7 apply to this waste stream estimate.
2	Package-specific equipment includes 40'/48' freight container
	lifting beam & pallet trucks for each site.
3	Assume transport packagings and package-specific equipment
	is shared for Trench waste. Cost for these is split proportional
	to number of packagings.

Section F: Total Waste Stream Transport Cost Estimate Summary					
1	Geology/Year DGR Available	Sedimentary 2045		Crystalline 2055	
2	One-Way Shipping Distance (km)	100	300	200	2,000
3	Total Transport Pack. Cost (Section C)	$1,146,384	$2,120,768	$1,633,576	$7,967,072
4	Total Road Transport Cost (Section D)	$13,216,037	$39,648,112	$ 27,970,572	$279,705,717
5	Packaging & Equip. Maintenance Cost	$54,319	$103,038	$78,679	$395,354
6	Total Base Cost	$14,416,741	$41,871,918	$29,682,827	$288,068,143
7	Uncertainty Adjustment Factor	1.1	1.2	1.15	1.4
8	Total Adjusted Base Cost	$15,858,415	$50,246,302	$34,135,250	$403,295,400

Table 3-2: Basis of Estimate for Packaging and Transporting Bruce Steam Generator Waste Category

	Section A: Bulk Waste Category Data	
1	Class (LLW or ILW)	LLW
2	Type	Non-processible
3	Physical Form	Contaminated Metal
4	Total Volume (m^3)	5,984
5	Total Mass (kg)	7.14E+06
6	Est. Total Activity (Bq)	1.86E+14
7	Est. Specific Activity (Bq/m^3)	3.10E+10
8	Est. Unshielded Dose Rate (mSv/hr)	90% < 10 & 10% > 10
9	Waste Class (LSA-II, SCO-II, A, B)	90% SCO-II and 10% A

	Section B: Waste Container(s) or Large Component Data			
1	Waste Container/Comp. Grouping	1		2
2	Type/Model	Steam Generator Segment		
3	General Descriptor	Segmented Component		
4	Outside Dimensions (LxWxH, m)	2.5-3.6 OD x 1.9-2.9 OL		
5	External/Gross Volume (m^3)	< 19.8 per segment (max)		
6	Max. Gross Weight (kg)	19,718-33,686 (grouted)		
7	Handling Method(s)	Crane		
8	DGR Emplacement Ready?	Yes		
9	Quantity	416	Segments	

	Section C: Transport Packaging & Equipment Estimate Inputs		
1	Transport Package Grouping	1	2
2	Transport Package Type (IP-2, A, B)	Type IP-2	Type A
3	Packaging Model/Descriptor	Self + Soft Packaging	
4	Qty. Waste Cont./Comp. per Package	1	1
5	Standard, Custom or Self Packaging?	Custom Soft Packaging	
6	Shielded or Unshielded Packaging?	Unshielded	Shielded
7	Reusable or One-Time Packaging?	One-time	One-time
8	New or Existing Packaging Design?	New	New
9	Packaging Design. & Licensing Cost	$20,000	$25,000
10	Packaging-Specific Equipment Cost	$64,800	
11	Transport Packaging Cost 100 km	$1,942,000	
12	Transport Packaging Cost 300 km	$2,914,000	
13	Transport Packaging Cost 200 km	$3,400,000	
14	Transport Packaging Cost 2,000 km	$5,344,000	

	Section D: Road Transport Operations Estimate Inputs				
1	Shipment Grouping	1		2	
2	Number of Shipments	384		32	
3	Rate of Shipments (#/day)	2		2	
4	Gross Transport Package Weight	< 60,000 lbs.	(< 27.2 Mt)	> 60,000 lbs.	(> 27.2 Mt)
5	Legal Size or Oversized Shipment?	Oversized	(≥ 2.6m wide)	Oversized	(≥ 2.6m wide)
6	Legal Weight or Overweight Shipment?	Legal Weight	(< 42.2 Mt)	Legal Weight	(> 42.2 Mt)
7	Standard, Extended or Heavy Trailer?	Extended		Extended, Heavy	
8	Oversized Escort Required?	Yes		Yes	
9	Geology/Year DGR Available	Sedimentary 2045		Crystalline 2055	
10	One-Way Shipping Distance (km)	100	300	200	2,000
11	Est. Round Trip Duration (days)	3	6	4.5	24
12	Qty. Transport Packagings Needed	416	416	416	416
13	Qty. Tractor/Trailer Equipment Sets	6	12	9	48
14	Est. Road Transport Trucking Cost	$1,245,088	$3,579,264	$1,944,176	$24,277,760

	Section E: Estimate Assumptions, Explanations & Qualifiers
1	See Table 3-13 for common assumptions.
	Assumptions 1, 2, 3, 6, 7, & 8 apply to this waste stream estimate.
2	SG segment data obtained from OPG 01098-REP-79137-0185255.
3	Assume all SG segments are oversized.
4	Package-specific equipment includes two SG segment lifting beams.
5	The quantity of reusable SG segment cradles & tiedown sets varies
	by dist. and # of trucks & are included in transport packaging costs.
6	Assume SG segment self-packaging meets Type IP-2 or Type A
	requirements. Assume supplemental soft packaging is the same for Type IP-2 & Type A segments.

	Section F: Total Waste Stream Transport Cost Estimate Summary				
1	Geology/Year DGR Available	Sedimentary 2045		Crystalline 2055	
2	One-Way Shipping Distance (km)	100	300	200	2,000
3	Total Transport Pack. Cost (Section C)	$2,051,800	$3,023,800	$3,509,800	$5,453,800
4	Total Road Transport Cost (Section D)	$1,245,088	$3,579,264	$1,944,176	$24,277,760
5	Packaging & Equip. Maintenance Cost	$27,540	$76,140	$100,440	$197,640
6	Total Base Cost	$3,324,428	$6,679,204	$5,554,416	$29,929,200
7	Uncertainty Adjustment Factor	1.1	1.2	1.15	1.4
8	Total Adjusted Base Cost	$3,656,871	$8,015,045	$6,387,578	$41,900,880

Table 3-3: Basis of Estimate for Packaging and Transporting Trench Waste Category

Section A: Bulk Waste Category Data		
1	Class (LLW or ILW)	LLW
2	Type	Non-Processible
3	Physical Form	Drums, Filters, Metal, etc.
4	Total Volume (m^3)	4,556
5	Total Mass (kg)	2.14E+06
6	Est. Total Activity (Bq)	Not Available
7	Est. Specific Activity (Bq/m^3)	Variable
8	Est. Unshielded Dose Rate (mSv/hr)	90% < 10 & 10% > 10
9	Waste Class (LSA-II, SCO-II, A, B)	90% LSA-II and 10% A

Section B: Waste Container(s) or Large Component Data			
1	Waste Container/Comp. Grouping	1	2
2	Type/Model	Non-Pro NPB47	DBIN1
3	General Descriptor	Stackable Box	Stackable Drum Bin
4	Outside Dimensions (LxWxH, m)	1.96 x 1.32 x 1.19	1.96 x 1.32 x 1.03
5	External/Gross Volume (m^3)	3.2	2.8
6	Max. Gross Weight (kg)	1,460	1,450
7	Handling Method(s)	Pallet Truck, Forklift, Crane	Pallet Truck, Forklift, Crane
8	DGR Emplacement Ready?	Yes	Yes
9	Quantity	1,494	432

Section C: Transport Packaging & Equipment Estimate Inputs			
1	Transport Package Grouping	1	2
2	Transport Package Type (IP-2, A, B)	Type IP-2	Type A
3	Packaging Model/Descriptor	40 ft. Freight Containers	
4	Qty. Waste Cont./Comp. per Package	8	8
5	Standard, Custom or Self Packaging?	Standard	Mod Standard
6	Shielded or Unshielded Packaging?	Unshielded	Shielded
7	Reusable or One-Time Packaging?	Reusable	Reusable
8	New or Existing Packaging Design?	Existing	Mod Existing
9	Packaging Design. & Licensing Cost	$30,000	
10	Packaging-Specific Equipment Cost	$112,000	
11	Transport Packaging Cost 100 km	$422,300	
12	Transport Packaging Cost 300 km	$844,600	
13	Transport Packaging Cost 200 km	$633,450	
14	Transport Packaging Cost 2,000 km	$3,378,400	

Section D: Road Transport Operations Estimate Inputs					
1	Shipment Grouping	1 (Type IP-2)		2 (Type A)	
2	Number of Shipments	217		24	
3	Rate of Shipments (#/day)	2		2	
4	Gross Transport Package Weight	< 40,000 lbs.	(< 18.1 Mt)	< 50,000 lbs.	(< 22.7 Mt)
5	Legal Size or Oversized Shipment?	Legal Size	(< 2.6m wide)	Legal Size	(< 2.6m wide)
6	Legal Weight or Overweight Ship.?	Legal Weight	(< 42.2 Mt)	Legal Weight	(< 42.2 Mt)
7	Standard, Extended or Heavy Trailer?	Standard		Standard	
8	Oversized Escort Required?	No		No	
9	Geology/Year DGR Available	Sedimentary 2045		Crystalline 2055	
10	One-Way Shipping Distance (km)	100	300	200	2,000
11	Est. Round Trip Duration (days)	1	2	1.5	8
12	Qty. Transport Packagings Needed	4	8	6	32
13	Qty. Tractor/Trailer Equipment Sets	2	4	3	16
14	Est. Road Transport Trucking Cost	$465,611	$1,396,832	$931,221	$9,312,210

Section E: Estimate Assumptions, Explanations & Qualifiers	
1	See Table 3-13 for common assumptions:
	Assumptions 1, 2, 3, 4, 5, 6, & 7 apply to this waste stream estimate.
2	Package-specific equipment includes 40'/48' freight container
	lifting beam & pallet trucks for each site.
3	Assume transport packagings and package-specific equipment
	is shared for Trench waste. Cost for these is split proportional
	to number of packagings.

Section F: Total Waste Stream Transport Cost Estimate Summary					
1	Geology/Year DGR Available	Sedimentary 2045		Crystalline 2055	
2	One-Way Shipping Distance (km)	100	300	200	2,000
3	Total Transport Pack. Cost (Section C)	$564,300	$986,600	$775,450	$3,520,400
4	Total Road Transport Cost (Section D)	$465,611	$1,396,832	$931,221	$9,312,210
5	Packaging & Equip. Maintenance Cost	$26,715	$47,830	$37,273	$174,520
6	Total Base Cost	$1,056,626	$2,431,262	$1,743,944	$13,007,130
7	Uncertainty Adjustment Factor	1.1	1.2	1.15	1.4
8	Total Adjusted Base Cost	$1,162,288	$2,917,514	$2,005,535	$18,209,982

Table 3-4: Basis of Estimate for Packaging and Transporting Heat Exchanger Waste Category

	Section A: Bulk Waste Category Data	
1	Class (LLW or ILW)	LLW
2	Type	Non-Processible
3	Physical Form	Contaminated Metal
4	Total Volume (m^3)	1,160
5	Total Mass (kg)	8.34E+05
6	Est. Total Activity (Bq)	3.48E+13
7	Est. Specific Activity (Bq/m^3)	3.00E+10
8	Est. Unshielded Dose Rate (mSv/hr)	90% < 10 & 10% > 10
9	Waste Class (LSA-II, SCO-II, A, B)	90% SCO-II and 10% A

	Section B: Waste Container(s) or Large Component Data		
1	Waste Container/Comp. Grouping	1	2
2	Type/Model	HX Intact	HX Segments
3	General Descriptor	Intact Component	Segmented Component
4	Outside Dimensions (LxWxH, m, intact)	0.91 to 1.83 x 1.52 to 7.62	2.44 to 2.95 x 6.55 to 7.01
5	External/Gross Volume (m^3, intact)	16 to 46	16 to 51
6	Max. Gross Weight (kg, intact)	8,000 to 20,000	27,000 to 35,000
7	Handling Method(s)	Crane	Crane
8	DGR Emplacement Ready?	Yes (assumed)	Yes (assumed)
9	Quantity	31	20

	Section C: Transport Packaging & Equipment Estimate Inputs		
1	Transport Package Grouping	1	2
2	Transport Package Type (IP-2, A, B)	Type IP-2	Type A
3	Packaging Model/Descriptor	20 & 40 ft. Freight Containers	
4	Qty. Waste Cont./Comp. per Package	1	1
5	Standard, Custom or Self Packaging?	Standard 40 ft., Custom 20 ft.	
6	Shielded or Unshielded Packaging?	Unshielded	Shielded
7	Reusable or One-Time Packaging?	Reusable	Reusable
8	New or Existing Packaging Design?	Existing & New for Oversized	
9	Packaging Design. & Licensing Cost	$100,000	
10	Package-Specific Equipment Cost	$64,800	
11	Transport Packaging Cost 100 km	$911,150	
12	Transport Packaging Cost 300 km	$1,822,300	
13	Transport Packaging Cost 200 km	$1,366,725	
14	Transport Packaging Cost 2,000 km	$7,289,200	

	Section D: Road Transport Operations Estimate Inputs				
1	Shipment Grouping (intact & segments)	1 (Type IP-2)		2 (Type A)	
2	Number of Shipments	46		5	
3	Rate of Shipments (#/day)	2		2	
4	Gross Transport Package Weight	< 60,000 lbs.	(< 27.2 Mt)	< 60,000 lbs.	(< 27.2 Mt)
5	Legal Size or Oversized Shipment?	Legal Size	(< 2.6m wide)	Legal Size	(< 2.6m wide)
6	Legal Weight or Overweight Shipment?	Legal Weight	(< 42.2 Mt)	Legal Weight	(< 42.2 Mt)
7	Standard, Extended or Heavy Trailer?	Standard		Standard	
8	Oversized Escort Required?	No		No	
9	Geology/Year DGR Available	Sedimentary 2045		Crystalline 2055	
10	One-Way Shipping Distance (km)	100	300	200	2,000
11	Est. Round Trip Duration (days)	1	2	1.5	8
12	Qty. Transport Packagings Needed	4	8	6	32
13	Qty. Tractor/Trailer Equipment Sets	2	4	3	16
14	Est. Road Transport Trucking Cost	$98,634	$295,902	$197,268	$1,972,680

	Section E: Estimate Assumptions, Explanations & Qualifiers
1	See Table 3-13 for common assumptions.
	Assumptions 1, 2, 3, 4, 5, 6, 7, & 8 apply to this estimate.
2	IHX size & weight data obtained from OPG W-CORR-79011-0318497.
3	Package-specific equipment includes two IHX segment lifting beams.

	Section F: Total Waste Stream Transport Cost Estimate Summary				
1	Geology/Year DGR Available	Sedimentary 2045		Crystalline 2055	
2	One-Way Shipping Distance (km)	100	300	200	2,000
3	Total Transport Pack. Cost (Section C)	$1,075,950	$1,987,100	$1,531,525	$7,454,000
4	Total Road Transport Cost (Section D)	$98,634	$295,902	$197,268	$1,972,680
5	Packaging & Equip. Maintenance Cost	$48,798	$94,355	$71,576	$367,700
6	Total Base Cost	$1,223,382	$2,377,357	$1,800,369	$9,794,380
7	Uncertainty Adjustment Factor	1.1	1.2	1.15	1.4
8	Total Adjusted Base Cost	$1,345,720	$2,852,828	$2,070,425	$13,712,132

Table 3-5: Basis of Estimate for Packaging and Transporting IC-2 Tile Hole Fixed Liners Bulk Waste Category

	Section A: Bulk Waste Category Data		
1	Class (LLW or ILW)	ILW	
2	Type	Non-Processible	
3	Physical Form	Filters, Vessels, Rx Comp., etc.	
4	Total Volume (m^3) (each, total)	2.15	43
5	Total Mass (kg) (each, total)	2,000	4.00E+04
6	Est. Total Activity (Bq)	Not Available	
7	Est. Specific Activity (Bq/m^3)	Variable	
8	Est. Unshielded Dose Rate (mSv/hr)	69.3% < 10 & 30.7% > 10	
9	Waste Class (LSA-II, SCO-II, A, B)	30% A and 70% B	

	Section B: Waste Container(s) or Large Component Data		
1	Waste Container/Comp. Grouping	1	2
2	Type/Model	IC-2 THL waste in MSC-4	IC-2 THL waste in MSC-6
3	General Descriptor	Robust Shielded Container	Robust Shielded Container
4	Outside Dimensions (LxWxH, m)	2.27X 1.84 X 1.73	
5	External/Gross Volume (m^3)	7.2	
6	Max. Gross Weight (kg)	20,000	27,000
7	Handling Method(s)	Forklift, Crane	
8	DGR Emplacement Ready?	Yes	Yes
9	Quantity	13	4

	Section C: Transport Packaging & Equipment Estimate Inputs		
1	Transport Package Grouping	1	2
2	Transport Package Type (IP-2, A, B)	Type A	Type B
3	Packaging Model/Descriptor	As-Is	In Overpack
	Qty. Waste Cont./Comp. per Package	1	1
4	Standard, Custom or Self Packaging?	Standard	Custom
5	Shielded or Unshielded Packaging?	Shielded	Shielded
6	Reusable or One-Time Packaging?	One-Time	Reusable
7	New or Existing Packaging Design?	Existing	New
8	Packaging Design. & Licensing Cost	$563,903	
9	Package-Specific Equipment Cost	$40,000	
10	Transport Packaging Cost 100 km	$2,617,082	
11	Transport Packaging Cost 300 km	$3,702,016	
12	Transport Packaging Cost 200 km	$3,159,549	
13	Transport Packaging Cost 2,000 km	$10,211,616	

	Section D: Road Transport Operations Estimate Inputs				
1	Shipment Grouping	1 (Type A)		2 (Type B)	
2	Number of Shipments	5		12	
3	Rate of Shipments (#/day)	2		2	
4	Gross Transport Package Weight (Mt)	< 27.2 Mt	(< 60,000 lbs.)	< 27.2 Mt	(< 60,000 lbs.)
5	Legal Size or Oversized Shipment?	Legal Size	(< 2.6m wide)	Legal Size	(< 2.6m wide)
6	Legal Weight or Overweight Ship.?	Legal Weight	(< 42.2 Mt)	Legal Weight	(< 42.2 Mt)
7	Standard, Extended or Heavy Truck?	Standard		Standard	
8	Oversized Escort Required?	No		No	
9	Geology/Year DGR Available	Sedimentary 2045		Crystalline 2055	
10	One-Way Shipping Distance (km)	100	300	200	2,000
11	Est. Round Trip Duration (days)	1	2	1.5	8
12	Qty. Transport Packagings Needed	1	2	2	8
13	Qty. Tractor/Trailer Equipment Sets	2	4	3	16
14	Est. Road Transport Cost	$32,878	$98,634	$65,756	$657,560

	Section E: Estimate Assumptions, Explanations & Qualifiers
1	See Table 3-13 for common assumptions.
	Assumptions 1, 4, 5, 6, 7, 9, & 11 apply to this estimate.
2	Type A waste ships in MSC as-is. No overpack or impact limiters.
3	Type B waste ships in MSC with an overpack and impact limiters.
4	20% packaging density lost from IC-2 THL to MSC.
5	80% waste volume in MSC-4's, 20% in MSC-6's.
6	Packaging-specific equipment includes MSC lift fixture for each site
	and sufficient tiedown sets for each distance.
7	Assume Type B overpacks & impact limiters and package-specific equipment is shared for THELs, IC-2 THLs and removable THLs. Cost for these is split evenly.

	Section F: Total Waste Stream Transport Cost Estimate Summary				
1	Geology/Year DGR Available	Sedimentary 2045		Crystalline 2055	
2	One-Way Shipping Distance (km)	100	300	200	2,000
3	Total Transport Pack. Cost (Section C)	$3,220,985	$4,305,919	$3,763,452	$10,815,519
4	Total Road Transport Cost (Section D)	$32,878	$98,634	$65,756	$657,560
5	Packaging & Equip. Maintenance Cost	$107,160	$214,320	$160,740	$857,280
6	Total Base Cost	$3,361,023	$4,618,873	$3,989,948	$12,330,359
7	Uncertainty Adjustment Factor	1.1	1.2	1.15	1.4
8	Total Adjusted Base Cost	$3,697,126	$5,542,647	$4,588,440	$17,262,502

Table 3-6: Basis of Estimate for Packaging and Transporting IC-2 Tile Hole Removable Liners Bulk Waste Category

Section A: Bulk Waste Category Data

1	Class (LLW or ILW)	ILW	
2	Type	Non-Processible	
3	Physical Form	Filters, Vessels, Rx Comp., etc.	
4	Total Volume (m^3) (each, total)	0.95	172
5	Total Mass (kg) (each, total)	1,550	2.81E+05
6	Est. Total Activity (Bq)	Not Available	
7	Est. Specific Activity (Bq/m^3)	Variable	
8	Est. Unshielded Dose Rate (mSv/hr)	69.3% < 10 & 30.7% > 10	
9	Waste Class (LSA-II, SCO-II, A, B)	30% A and 70% B	

Section B: Waste Container(s) or Large Component Data

1	Waste Container/Comp. Grouping	1	2
2	Type/Model	Remov. THL waste in MSC-4	Remov. THL waste in MSC-6
3	General Descriptor	Robust Shielded Container	Robust Shielded Container
4	Outside Dimensions (LxWxH, m)	2.27X 1.84 X 1.73	
5	External/Gross Volume (m^3)	7.2	
6	Max. Gross Weight (kg)	20,000	27,000
7	Handling Method(s)	Forklift, Crane	
8	DGR Emplacement Ready?	Yes	Yes
9	Quantity	50	16

Section C: Transport Packaging & Equipment Estimate Inputs

1	Transport Package Grouping	1	2
2	Transport Package Type (IP-2, A, B)	Type A	Type B
3	Packaging Model/Descriptor	As-Is	In Overpack
	Qty. Waste Cont./Comp. per Package	1	1
4	Standard, Custom or Self Packaging?	Standard	Custom
5	Shielded or Unshielded Packaging?	Shielded	Shielded
6	Reusable or One-Time Packaging?	One-Time	Reusable
7	New or Existing Packaging Design?	Existing	New
8	Packaging Design. & Licensing Cost	$563,903	
9	Package-Specific Equipment Cost	$40,000	
10	Transport Packaging Cost 100 km	$7,041,207	
11	Transport Packaging Cost 300 km	$8,126,141	
12	Transport Packaging Cost 200 km	$7,583,674	
13	Transport Packaging Cost 2,000 km	$14,635,741	

Section D: Road Transport Operations Estimate Inputs

1	Shipment Grouping	1 (Type A)		2 (Type B)	
2	Number of Shipments	20		46	
3	Rate of Shipments (#/day)	2		2	
4	Gross Transport Package Weight (Mt)	< 27.2 Mt	(< 60,000 lbs.)	< 27.2 Mt	(< 60,000 lbs.)
5	Legal Size or Oversized Shipment?	Legal Size	(< 2.6m wide)	Legal Size	(< 2.6m wide)
6	Legal Weight or Overweight Ship.?	Legal Weight	(< 42.2 Mt)	Legal Weight	(< 42.2 Mt)
7	Standard, Extended or Heavy Truck?	Standard		Standard	
8	Oversized Escort Required?	No		No	
9	Geology/Year DGR Available	Sedimentary 2045		Crystalline 2055	
10	One-Way Shipping Distance (km)	100	300	200	2,000
11	Est. Round Trip Duration (days)	1	2	1.5	8
12	Qty. Transport Packagings Needed	1	2	2	8
13	Qty. Tractor/Trailer Equipment Sets	2	4	3	16
14	Est. Road Transport Cost	$127,644	$382,932	$255,288	$2,552,880

Section E: Estimate Assumptions, Explanations & Qualifiers

1 See Table 3-13 for common assumptions.
Assumptions 1, 4, 5, 6, 7, 9, & 11 apply to this estimate.
2 Type A waste ships in MSC as-is. No overpack or impact limiters.
3 Type B waste ships in MSC with an overpack and impact limiters.
4 20% packaging density lost from IC-2 THL to MSC.
5 80% waste volume in MSC-4's, 20% in MSC-6's.
6 Packaging-specific equipment includes MSC lift fixture for each site and sufficient tiedown sets for each distance.
7 Assume Type B overpacks & impact limiters and package-specific equipment is shared for THELs, IC-2 THLs and removable THLs. Cost for these is split evenly.

Section F: Total Waste Stream Transport Cost Estimate Summary

1	Geology/Year DGR Available	Sedimentary 2045		Crystalline 2055	
2	One-Way Shipping Distance (km)	100	300	200	2,000
3	Total Transport Pack. Cost (Section C)	$7,645,110	$8,730,044	$8,187,577	$15,239,644
4	Total Road Transport Cost (Section D)	$127,644	$382,932	$255,288	$2,552,880
5	Packaging & Equip. Maintenance Cost	$107,160	$214,320	$160,740	$857,280
6	Total Base Cost	$7,879,914	$9,327,296	$8,603,605	$18,649,804
7	Uncertainty Adjustment Factor	1.1	1.2	1.15	1.4
8	Total Adjusted Base Cost	$8,667,906	$11,192,755	$9,894,146	$26,109,725

Table 3-7: Basis of Estimate for Packaging and Transporting Quadricell Resin Liners Waste Category

Section A: Bulk Waste Category Data			
1	Class (LLW or ILW)	ILW	
2	Type	Stabilized Wet Waste	
3	Physical Form	Dewatered IX Resin Beads	
4	Total Volume (m^3) (each, total)	3	345
5	Total Mass (kg) (each, total)	3,750	4.31E+05
6	Est. Total Activity (Bq)	1.24E+15	
7	Est. Specific Activity (Bq/m^3)	3.6E+12	
8	Est. Unshielded Dose Rate (mSv/hr)	49.5% < 10 & 50.5% > 10	
9	Waste Class (LSA-II, SCO-II, A, B)	30% A and 70% B	

Section B: Waste Container(s) or Large Component Data			
1	Waste Container/Comp. Grouping	1	2
2	Type/Model	Overpacked Carbon Steel Liner	
3	General Descriptor	Unshielded Resin Liner	
4	Outside Dimensions (LxWxH, m)	1.68 OD x 1.91 OL SS Overpack	
5	External/Gross Volume (m^3)	4.23	
6	Max. Gross Weight (kg)	6,000 Overpacked	
7	Handling Method(s)	Crane & Shielding Bell	
8	DGR Emplacement Ready?	Yes (w/ shielded overpack)	
9	Quantity	115	

Section C: Transport Packaging & Equipment Estimate Inputs			
1	Transport Package Grouping	1	2
2	Transport Package Type (IP-2, A, B)	Type A	Type B
3	Packaging Model/Descriptor	Freight Cont.	Trillium Flask
4	Qty. Waste Cont./Comp. per Package	2	1
5	Standard, Custom or Self Packaging?	Standard	Custom
6	Shielded or Unshielded Packaging?	Shielded	Heavy Shield.
7	Reusable or One-Time Packaging?	Reusable	Reusable
8	New or Existing Packaging Design?	Existing	Existing
9	Packaging Design. & Licensing Cost	$25,000	
10	Package-Specific Equipment Cost	$360,000	
11	Transport Packaging Cost 100 km	$2,055,296	
12	Transport Packaging Cost 300 km	$4,110,591	
13	Transport Packaging Cost 200 km	$3,082,943	
14	Transport Packaging Cost 2,000 km	$16,442,364	

Section D: Road Transport Operations Estimate Inputs					
1	Shipment Grouping	1 (Type A)		2 (Type B)	
2	Number of Shipments	17		81	
3	Rate of Shipments (#/day)	2		2	
4	Gross Transport Package Weight (Mt)	< 27.2 Mt	(< 60,000 lbs.)	< 27.2 Mt	(< 60,000 lbs.)
5	Legal Size or Oversized Shipment?	Legal Size	(< 2.6m wide)	Legal Size	(< 2.6m wide)
6	Legal Weight or Overweight Ship.?	Legal Weight	(< 42.2 Mt)	Legal Weight	(< 42.2 Mt)
7	Standard, Extended or Heavy Truck?	Standard		Standard	
8	Oversized Escort Required?	No		No	
9	Geology/Year DGR Available	Sedimentary 2045		Crystalline 2055	
10	One-Way Shipping Distance (km)	100	300	200	2,000
11	Est. Round Trip Duration (days)	1	2	1.5	8
12	Qty. Transport Packagings Needed	2	3	2	12
13	Qty. Tractor/Trailer Equipment Sets	2	4	3	16
14	Est. Road Transport Cost	$189,049	$567,146	$378,097	$3,780,970

Section F: Total Waste Stream Transport Cost Estimate Summary					
1	Geology/Year DGR Available	Sedimentary 2045		Crystalline 2055	
2	One-Way Shipping Distance (km)	100	300	200	2,000
3	Total Transport Pack. Cost (Section C)	$2,440,296	$4,495,591	$3,467,943	$16,827,364
4	Total Road Transport Cost (Section D)	$189,049	$567,146	$378,097	$3,780,970
5	Packaging & Equip. Maintenance Cost	$120,765	$223,530	$172,147	$840,118
6	Total Base Cost	$2,750,109	$5,286,266	$4,018,187	$21,448,452
7	Uncertainty Adjustment Factor	1.1	1.2	1.15	1.4
8	Total Adjusted Base Cost	$3,025,120	$6,343,519	$4,620,916	$30,027,833

Section E: Estimate Assumptions, Explanations & Qualifiers	
1	See Table 3-13 for common assumptions.
	Assumptions 1, 4, 5, 6, 7, 9, & 10 apply to this estimate.
2	Assume carbon steel RLs are already overpacked in stainless.
3	Assume individual unshielded RLs are retrieved from Quadricell
	storage & transferred to packaging using shielding bell.
4	Shielded Type A freight container has capacity for 3 RLs, but is
	assumed to be short loaded with 2 RLs to avoid being overweight.
5	Package-specific equipment includes flask lifting yoke, RL lifting
	beam & shielded transfer bell for each site. It also includes dedicated flask transport trailer with tiedown sets for each distance.
6	Assume transport packagings and package-specific equipment is shared for Quadricell and IC-12 & IC-18 RLs. Cost for these is split evenly.

Table 3-8: Basis of Estimate for Packaging and Transporting IC-12/IC-18 Resin Liners Waste Category

Section A: Bulk Waste Category Data			
1	Class (LLW or ILW)	ILW	
2	Type	Stabilized Wet Waste	
3	Physical Form	Dewatered IX Resin Beads	
4	Total Volume (m^3) (2045, 2055)	6,249	6,867
5	Total Mass (kg) (2045, 2055)	7.81E+06	8.58E+06
6	Est. Total Activity (Bq)	2.25E+16	2.47E+16
7	Est. Specific Activity (Bq/m^3)	3.6E+12	
8	Est. Unshielded Dose Rate (mSv/hr)	49.5% < 10 & 50.5% > 10	
9	Waste Class (LSA-II, SCO-II, A, B)	30% A and 70% B	

Section B: Waste Container(s) or Large Component Data					
1	Waste Container/Comp. Grouping	1		2	
2	Type/Model	Overpacked Carbon Steel Liner		Stainless Steel Liner	
3	General Descriptor	Unshielded Resin Liner		Unshielded Resin Liner	
4	Outside Dimensions (LxWxH, m)	1.68 OD x 1.91 OL SS Overpack		1.63 OD x 1.80 OL	
5	External/Gross Volume (m^3)	4.23		3.76	
6	Max. Gross Weight (kg)	6,000 Overpacked		4,500	
7	Handling Method(s)	Crane & Shielding Bell		Crane & Shielding Bell	
8	DGR Emplacement Ready?	Yes (w/ shielded overpack)		Yes (w/ shielded overpack)	
9	Quantity (2045, 2055)	585	585	1,498	1,704

Section C: Transport Packaging & Equipment Estimate Inputs			
1	Transport Package Grouping	1	2
2	Transport Package Type (IP-2, A, B)	Type A	Type B
3	Packaging Model/Descriptor	Freight Cont.	Trillium Flask
4	Qty. Waste Cont./Comp. per Package	2	1
5	Standard, Custom or Self Packaging?	Standard	Custom
6	Shielded or Unshielded Packaging?	Shielded	Heavy Shield.
7	Reusable or One-Time Packaging?	Reusable	Reusable
8	New or Existing Packaging Design?	Existing	Existing
9	Packaging Design. & Licensing Cost	$25,000	
10	Package-Specific Equipment Cost	$360,000	
11	Transport Packaging Cost 100 km	$2,055,296	
12	Transport Packaging Cost 300 km	$4,110,591	
13	Transport Packaging Cost 200 km	$3,082,943	
14	Transport Packaging Cost 2,000 km	$16,442,364	

Section D: Road Transport Operations Estimate Inputs					
1	Shipment Grouping	1 (Type A)		2 (Type B)	
2	Number of Shipments (2045, 2055)	312	343	1,458	1,602
3	Rate of Shipments (#/day)	2		2	
4	Gross Transport Package Weight (Mt)	< 27.2 Mt	(< 60,000 lbs.)	< 27.2 Mt	(< 60,000 lbs.)
5	Legal Size or Oversized Shipment?	Legal Size	(< 2.6m wide)	Legal Size	(< 2.6m wide)
6	Legal Weight or Overweight Ship.?	Legal Weight	(< 42.2 Mt)	Legal Weight	(< 42.2 Mt)
7	Standard, Extended or Heavy Truck?	Standard		Standard	
8	Oversized Escort Required?	No		No	
9	Geology/Year DGR Available	Sedimentary 2045		Crystalline 2055	
10	One-Way Shipping Distance (km)	100	300	200	2,000
11	Est. Round Trip Duration (days)	1	2	1.5	8
12	Qty. Transport Packagings Needed	2	3	2	12
13	Qty. Tractor/Trailer Equipment Sets	2	4	3	16
14	Est. Road Transport Cost	$3,424,244	$10,272,731	$7,525,774	$75,257,742

Section E: Estimate Assumptions, Explanations & Qualifiers	
1	See Table 3-13 for common assumptions.
	Assumptions 1, 4, 5, 6, 7, 9, & 10 apply to this estimate.
2	Assume carbon steel RLs are already overpacked in stainless.
3	Assume individual unshielded RLs are retrieved from IC-12 & IC-18
	storage & transferred to packaging using shielding bell.
4	Shielded Type A freight container has capacity for 3 RLs, but is
	assumed to be short loaded with 2 RLs to avoid being overweight.
5	Package-specific equipment includes flask lifting yoke, RL lifting
	beam & shielded transfer bell for each site. It also includes dedicated flask transport trailer with tiedown sets for each distance.
6	Assume transport packagings and package-specific equipment is shared for Quadricell and IC-12 & IC-18 RLs. Cost for these is split evenly.

Section F: Total Waste Stream Transport Cost Estimate Summary					
1	Geology/Year DGR Available	Sedimentary 2045		Crystalline 2055	
2	One-Way Shipping Distance (km)	100	300	200	2,000
3	Total Transport Pack. Cost (Section C)	$2,440,296	$4,495,591	$3,467,943	$16,827,364
4	Total Road Transport Cost (Section D)	$3,424,244	$10,272,731	$7,525,774	$75,257,742
5	Packaging & Equip. Maintenance Cost	$120,765	$223,530	$172,147	$840,118
6	Total Base Cost	$5,985,304	$14,991,852	$11,165,865	$92,925,224
7	Uncertainty Adjustment Factor	1.1	1.2	1.15	1.4
8	Total Adjusted Base Cost	$6,583,834	$17,990,222	$12,840,744	$130,095,314

Table 3-9: Basis of Estimate for Packaging and Transporting IC-18 Tile Hole Equivalent Liner Waste Category

	Section A: Bulk Waste Category Data		
1	Class (LLW or ILW)	ILW	
2	Type	Non-Processible	
3	Physical Form	Filters, Vessels, Rx Comp., etc.	
4	Total Volume (m^3) (2045, 2055)	1,607	1,822
5	Total Mass (kg) (2045, 2055)	1.57E+06	1.78E+06
6	Est. Total Activity (Bq)	Not Available	
7	Est. Specific Activity (Bq/g)	Variable	
8	Est. Unshielded Dose Rate (mSv/hr)	69.3% < 10 & 30.7% > 10	
9	Waste Class (LSA-II, SCO-II, A, B)	30% A and 70% B	

	Section B: Waste Container(s) or Large Component Data				
1	Waste Container/Comp. Grouping	1		2	
2	Type/Model	THEL waste in MSC-4		THEL waste in MSC-6	
3	General Descriptor	Robust Shielded Container		Robust Shielded Container	
4	Outside Dimensions (LxWxH, m)	2.27X 1.84 X 1.73			
5	External/Gross Volume (m^3)	7.2			
6	Max. Gross Weight (kg)	20,000		27,000	
7	Handling Method(s)	Forklift, Crane			
8	DGR Emplacement Ready?	Yes		Yes	
9	Quantity (2045, 2055)	469	532	147	166

	Section C: Transport Packaging & Equipment Estimate Inputs		
1	Transport Package Grouping	1	2
2	Transport Package Type (IP-2, A, B)	Type A	Type B
3	Packaging Model/Descriptor	As-Is	In Overpack
	Qty. Waste Cont./Comp. per Package	1	1
4	Standard, Custom or Self Packaging?	Standard	Custom
5	Shielded or Unshielded Packaging?	Shielded	Shielded
6	Reusable or One-Time Packaging?	One-Time	Reusable
7	New or Existing Packaging Design?	Existing	New
8	Packaging Design. & Licensing Cost	$563,903	
9	Package-Specific Equipment Cost	$40,000	
10	Transport Packaging Cost 100 km	$56,637,500	
11	Transport Packaging Cost 300 km	$57,722,434	
12	Transport Packaging Cost 200 km	$64,565,376	
13	Transport Packaging Cost 2,000 km	$71,617,443	

	Section D: Road Transport Operations Estimate Inputs				
1	Shipment Grouping	1 (Type A)		2 (Type B)	
2	Number of Shipments (2045, 2055)	185	209	431	489
3	Rate of Shipments (#/day)	2		2	
4	Gross Transport Package Weight (Mt)	< 27.2 Mt	(< 60,000 lbs.)	< 27.2 Mt	(< 60,000 lbs.)
5	Legal Size or Oversized Shipment?	Legal Size	(< 2.6m wide)	Legal Size	(< 2.6m wide)
6	Legal Weight or Overweight Ship.?	Legal Weight	(< 42.2 Mt)	Legal Weight	(< 42.2 Mt)
7	Standard, Extended or Heavy Truck?	Standard		Standard	
8	Oversized Escort Required?	No		No	
9	Geology/Year DGR Available	Sedimentary 2045		Crystalline 2055	
10	One-Way Shipping Distance (km)	100	300	200	2,000
11	Est. Round Trip Duration (days)	1	2	1.5	8
12	Qty. Transport Packagings Needed	1	2	2	8
13	Qty. Tractor/Trailer Equipment Sets	2	4	3	16
14	Est. Road Transport Cost	$1,191,344	$3,574,032	$2,699,864	$26,998,640

	Section E: Estimate Assumptions, Explanations & Qualifiers
1	See Table 3-13 for common assumptions.
	Assumptions 1, 4, 5, 6, 7, 9, & 11 apply to this estimate.
2	Type A waste ships in MSC as-is. No overpack or impact limiters.
3	Type B waste ships in MSC with an overpack and impact limiters.
4	20% packaging density lost from IC-2 THL to MSC.
5	80% waste volume in MSC-4's, 20% in MSC-6's.
6	Packaging-specific equipment includes MSC lift fixture for each site
	and sufficient tiedown sets for each distance.
7	Assume Type B overpacks & impact limiters and package-specific equipment is shared for THELs, IC-2 THLs and removable THLs. Cost for these is split evenly.
8	Higher adjustment factors reflect greater unkowns for future bulk waste repackaging at this time given the variability of the bulk waste item physical forms.

	Section F: Total Waste Stream Transport Cost Estimate Summary				
1	Geology/Year DGR Available	Sedimentary 2045		Crystalline 2055	
2	One-Way Shipping Distance (km)	100	300	200	2,000
3	Total Transport Pack. Cost (Section C)	$57,241,403	$58,326,337	$65,169,279	$72,221,346
4	Total Road Transport Cost (Section D)	$1,191,344	$3,574,032	$2,699,864	$26,998,640
5	Packaging & Equip. Maintenance Cost	$107,160	$214,320	$160,740	$857,280
6	Total Base Cost	$58,539,907	$62,114,689	$68,029,883	$100,077,266
7	Uncertainty Adjustment Factor	1.15	1.25	1.2	1.45
8	Total Adjusted Base Cost	$67,320,893	$77,643,361	$81,635,860	$145,112,035

Table 3-10: Basis of Estimate for Packaging and Transporting IC-2 Grouted Tile Hole Liners Waste Category

Section A: Bulk Waste Category Data			
1	Class (LLW or ILW)	ILW	
2	Type	Non-Processible	
3	Physical Form	Filters, Vessels, Rx Comp., etc.	
4	Total Volume (m^3) (each, total)	7.6	327
5	Total Mass (kg) (each, total)	25,000	1.08E+06
6	Est. Total Activity (Bq)	9.80E+12	
7	Est. Specific Activity (Bq/m^3)	3.00E+10	
8	Est. Unshielded Dose Rate (mSv/hr)	70% < 10 & 30% > 10	
9	Waste Class (LSA-II, SCO-II, A, B)	30% A and 70% B	

Section B: Waste Container(s) or Large Component Data			
1	Waste Container/Comp. Grouping	1	2
2	Type/Model	ETH	
3	General Descriptor	Encapsulated Tile Hole	
4	Outside Dimensions (LxWxH, m)	1.5 OD x 4.6 OL	
5	External/Gross Volume (m^3)	8.1	
6	Max. Gross Weight (kg)	25,000	
7	Handling Method(s)	Crane/Forklift	
8	DGR Emplacement Ready?	Yes	
9	Quantity	43	

Section C: Transport Packaging & Equipment Estimate Inputs			
1	Transport Package Grouping	1	2
2	Transport Package Type (IP-2, A, B)	Type A	Type B
3	Packaging Model/Descriptor	20' Frght. Cont.	Overpack
4	Qty. Waste Cont./Comp. per Package	1	1
5	Standard, Custom or Self Packaging?	Standard	Custom
6	Shielded or Unshielded Packaging?	Shielded	Unshielded
7	Reusable or One-Time Packaging?	Reusable	Reusable
8	New or Existing Packaging Design?	Existing	New
9	Packaging Design. & Licensing Cost	$1,691,709	
10	Packaging-Specific Equipment Cost	$120,000	
11	Transport Packaging Cost 100 km	$4,859,662	
12	Transport Packaging Cost 300 km	$9,719,325	
13	Transport Packaging Cost 200 km	$9,686,925	
14	Transport Packaging Cost 2,000 km	$23,373,187	

Section D: Road Transport Operations Estimate Inputs					
1	Shipment Grouping	1 (Type A)		2 (Type B)	
2	Number of Shipments	13		30	
3	Rate of Shipments (#/day)	2		2	
4	Gross Transport Package Weight (Mt)	> 27.2 Mt	(> 60,00 lbs.)	> 27.2 Mt	(> 60,00 lbs.)
5	Legal Size or Oversized Shipment?	Legal Size	(< 2.6m wide)	Legal Size	(< 2.6m wide)
6	Legal Weight or Overweight Shipment?	Overweight	(> 42.2 Mt)	Overweight	(> 42.2 Mt)
7	Standard, Extended or Heavy Trailer?	Heavy		Heavy	
8	Oversized Escort Required?	No		No	
9	Geology/Year DGR Available	Sedimentary 2045		Crystalline 2055	
10	One-Way Shipping Distance (km)	100	300	200	2,000
11	Est. Round Trip Duration (days)	3	6	4.5	24
12	Qty. Transport Packagings Needed	9	18	18	43
13	Qty. Tractor/Trailer Equipment Sets	6	12	9	43
14	Est. Road Transport Cost	$112,574	$337,722	$225,148	$2,251,480

Section E: Estimate Assumptions, Explanations & Qualifiers	
1	See Table 3-13 for common assumptions.
	Assumptions 1, 4, 6, 7, 8, 9, & 11 apply to this estimate.
2	Assume ETH is grouted, extracted, encap. & packaged as such.
3	Assume grouting itself provides sufficient shielding for transport.
4	Packaging-specific equipment includes a lift fixture for each site
	and sufficient Type A cradles & Type B tiedown sets for each distance.

Section F: Total Waste Stream Transport Cost Estimate Summary					
1	Geology/Year DGR Available	Sedimentary 2045		Crystalline 2055	
2	One-Way Shipping Distance (km)	100	300	200	2,000
3	Total Transport Pack. Cost (Section C)	$6,671,371	$11,531,034	$11,498,634	$25,184,896
4	Total Road Transport Cost (Section D)	$112,574	$337,722	$225,148	$2,251,480
5	Packaging & Equip. Maintenance Cost	$248,983	$491,966	$490,346	$1,174,659
6	Total Base Cost	$7,032,929	$12,360,722	$12,214,128	$28,611,036
7	Uncertainty Adjustment Factor	1.1	1.2	1.15	1.4
8	Total Adjusted Base Cost	$7,736,221	$14,832,867	$14,046,247	$40,055,450

Table 3-11: Basis of Estimate for Packaging and Transporting Bruce RWC Waste Category

	Section A: Bulk Waste Category Data		
1	Class (LLW or ILW)	ILW	
2	Type	Non-Processible	
3	Physical Form	Activated/Contam. Metal	
4	Total Volume (m^3) (per unit, total)	115	920
5	Total Mass (kg) (per unit, total)	2.51E+05	2.01E+06
6	Est. Total Activity (TBq)	Unavailable	
7	Est. Specific Activity (Bq/g)	1.40 to 1.66E+6 ^{60}Co @ 30 yr.	
8	Est. Unshielded Dose Rate (mSv/hr)	0-50% < 100, 50-100% > 100	
9	Waste Class (LSA-II, SCO-II, A, B)	0% to 50% A, 50% to 100% B	

	Section B: Waste Container(s) or Large Component Data		
1	Waste Container/Comp. Grouping	1	2
2	Type/Model	RWC(PT)	RWC(EF)
3	General Descriptor	PT/CT/CTI Fuel Channels	EF Fuel Channels
4	Outside Dimensions (LxWxH, m)	1.85x1.85x2.25	1.70x3.35x1.92
5	External/Gross Volume (m^3)	7.7	10.9
6	Max. Gross Weight (kg)	29,100	33,500
7	Handling Method(s)	Heavy Forklift, Crane	Heavy Forklift, Crane
8	DGR Emplacement Ready?	Yes	Yes
9	Quantity	304	408

	Section C: Transport Packaging & Equipment Estimate Inputs		
1	Transport Package Grouping	1	2
2	Transport Package Type (IP-2, A, B)	Type A	Type B
3	Packaging Model/Descriptor	RWC As-Is	w/Overpack
4	Qty. Waste Cont./Comp. per Package	1	1
5	Standard, Custom or Self Packaging?	N/A	Custom
6	Shielded or Unshielded Packaging?	Shielded	Unshielded
7	Reusable or One-Time Packaging?	One-Time	Reusable
8	New or Existing Packaging Design?	Existing	New
9	Packaging Design. & Licensing Cost	$1,691,709	
10	Packaging-Specific Equipment Cost	$120,000	
11	Transport Packaging Cost 100 km	$9,764,400	
12	Transport Packaging Cost 300 km	$19,528,800	
13	Transport Packaging Cost 200 km	$14,646,600	
14	Transport Packaging Cost 2,000 km	$78,115,200	

	Section D: Road Transport Operations Estimate Inputs				
1	Shipment Grouping	1 (Type A)		2 (Type B)	
2	Number of Shipments	140		572	
3	Rate of Shipments (#/day)	2		2	
4	Gross Transport Package Weight (Mt)	> 27.2 Mt	(> 60,00 lbs.)	> 27.2 Mt	(> 60,00 lbs.)
5	Legal Size or Oversized Shipment?	Legal Size	(< 2.6m wide)	Oversized	(> 2.6m wide)
6	Legal Weight or Overweight Shipment?	Overweight	(> 42.2 Mt)	Overweight	(> 42.2 Mt)
7	Standard, Extended or Heavy Trailer?	Heavy		Heavy	
8	Oversized Escort Required?	No		Yes	
9	Geology/Year DGR Available	Sedimentary 2045		Crystalline 2055	
10	One-Way Shipping Distance (km)	100	300	200	2,000
11	Est. Round Trip Duration (days)	3	6	4.5	24
12	Qty. Transport Packagings Needed	9	18	14	72
13	Qty. Tractor/Trailer Equipment Sets	6	12	9	48
14	Est. Road Transport Cost	$2,078,516	$6,021,048	$3,406,282	$40,712,320

	Section E: Estimate Assumptions, Explanations & Qualifiers
1	Assume 102 EF and 76 PT/CT/CTI RWCs are for two units.
2	Assume PT/CT/CTI RWCs for U1&2 are 50% Type A and 50% Type B. EF RWCs for U1&2 are all Type A. The U1&2 RWCs are existing.
3	Assume RWCs for U3-8 are all Type B since these are future RWCs.
4	Section A waste data from Bruce Power 21RT-79100-ASD-001.
5	Section B waste container data from OPG 00216-REP-03902-00003.
6	Section C assume same Type B overpack design used for both RWCs.
7	Packaging-specific equipment includes RWC lift fixture for each site and sufficient tiedown sets for both packaging types and each distance.
8	See Table 3-13 for common assumptions. Assumptions 4, 6, 7, 8, & 11 apply to this estimate.
9	Higher adjustment factors reflect greater unkowns for future U3-8 at this time, given that the RWCs have not yet been designed.

	Section F: Total Waste Stream Transport Cost Estimate Summary				
1	Geology/Year DGR Available	Sedimentary 2045		Crystalline 2055	
2	One-Way Shipping Distance (km)	100	300	200	2,000
3	Total Transport Pack. Cost (Section C)	$11,576,109	$21,340,509	$16,458,309	$79,926,909
4	Total Road Transport Cost (Section D)	$2,078,516	$6,021,048	$3,406,282	$40,712,320
5	Packaging & Equip. Maintenance Cost	$0	$0	$0	$0
6	Total Base Cost	$13,654,625	$27,361,557	$19,864,591	$120,639,229
7	Uncertainty Adjustment Factor	1.15	1.25	1.2	1.45
8	Total Adjusted Base Cost	$15,702,819	$34,201,946	$23,837,509	$174,926,882

Table 3-12: Basis of Estimate for Packaging and Transporting Darlington RWC Waste Category

Section A: Bulk Waste Stream Data			
1	Class (LLW or ILW)	ILW	
2	Type	Non-Processible	
3	Physical Form	Activated/Contam. Metal	
4	Total Volume (m^3) (per unit, total)	123	493
5	Total Mass (kg) (per unit, total)	2.69E+05	1.08E+06
6	Est. Total Activity (TBq)	5.5E+13 to 4.5E+14 @ 30 yr.	
7	Est. Specific Activity (Bq/g)	6.09E+5 to 5.26E+7 @ 25 yr.	
8	Est. Unshielded Dose Rate (mSv/hr)	> 100 and > A_2 Quantities	
9	Waste Class (LSA-II, SCO-II, A, B)	Assume 100% B	

Section B: Waste Container(s) or Large Component Data			
1	Waste Container/Comp. Grouping	1	2
2	Type/Model	D-RWC	
3	General Descriptor	EF/PT/CT/CTI Fuel Channels	
4	Outside Dimensions (LxWxH, m)	1.92 OD x 2.47 OH	
5	External/Gross Volume (m^3)	22.5	
6	Max. Gross Weight (kg)	25,000	
7	Handling Method(s)	Heavy Forklift, Crane	
8	DGR Emplacement Ready?	Yes	
9	Quantity	474	

Section C: Transport Packaging & Equipment Estimate Inputs			
1	Transport Package Grouping	1	2
2	Transport Package Type (IP-2, A, B)	Type B	
3	Packaging Model/Descriptor	Impact Limiters Only	
4	Qty. Waste Cont./Comp. per Package	1	
5	Standard, Custom or Self Packaging?	Custom	
6	Shielded or Unshielded Packaging?	Shielded	
7	Reusable or One-Time Packaging?	Reusable	
8	New or Existing Packaging Design?	Existing	
9	Packaging Design. & Licensing Cost	$50,000	
10	Package-Specific Equipment Cost	$120,000	
11	Transport Packaging Cost 100 km	$18,000	
12	Transport Packaging Cost 300 km	$36,000	
13	Transport Packaging Cost 200 km	$27,000	
14	Transport Packaging Cost 2,000 km	$144,000	

Section D: Road Transport Operations Estimate Inputs					
1	Shipment Grouping	1		2	
2	Number of Shipments	474			
3	Rate of Shipments (#/day)	2			
4	Gross Transport Package Weight (Mt)	< 27.2 Mt	(< 60,00 lbs.)		
5	Legal Size or Oversized Shipment?	Legal Size	(< 2.6m wide)		
6	Legal Weight or Overweight Shipment?	Legal Weight	(< 42.2 Mt)		
7	Standard, Extended or Heavy Truck?	Standard			
8	Oversized Escort Required?	No			
9	Geology/Year DGR Available	Sedimentary 2045		Crystalline 2055	
10	One-Way Shipping Distance (km)	100	300	200	2,000
11	Est. Round Trip Duration (days)	1	2	1.5	8
12	Qty. Transport Packagings Needed	3	6	5	24
13	Qty. Tractor/Trailer Equipment Sets	2	4	3	16
14	Est. Road Transport Cost	$916,716	$2,750,148	$1,833,432	$18,334,320

Section E: Estimate Assumptions, Explanations & Qualifiers	
1	Assume all D-RWCs are Type B since these are future RWCs.
2	Section A waste data from OPG 00044-REP-03460-00002.
3	Section B waste container data from OPG 00044-DR-79146-00001.
4	Assume D-RWC is already removed from DSO and transport lid is already installed. Assume D-RWC provides Type B containment.
5	Assume Type B packaging includes only impact limiters. No cost for impact limiters included since Darlington RWCs will have been previously transported to WWMF and they should already exist.
6	Assume D-RWC is already CNSC Type B certified. Assume 5 total CNSC transport certification renewals (1 every 5 years).
7	Packaging-specific equipment includes RWC lift fixture for each site and sufficient tiedowns for each distance.
8	See Table 3-13 for common assumptions. Assumptions 4, 5, 6, & 7 apply to this estimate.

Section F: Total Waste Stream Transport Cost Estimate Summary					
1	Geology/Year DGR Available	Sedimentary 2045		Crystalline 2055	
2	One-Way Shipping Distance (km)	100	300	200	2,000
3	Total Transport Pack. Cost (Section C)	$188,000	$206,000	$197,000	$314,000
4	Total Road Transport Cost (Section D)	$916,716	$2,750,148	$1,833,432	$18,334,320
5	Packaging & Equip. Maintenance Cost	$13,800	$15,600	$14,700	$26,400
6	Total Base Cost	$1,118,516	$2,971,748	$2,045,132	$18,674,720
7	Uncertainty Adjustment Factor	1.1	1.2	1.15	1.4
8	Total Adjusted Base Cost	$1,230,368	$3,566,098	$2,351,902	$26,144,608

Table 3-13: Common Assumptions for Basis of Estimate for Packaging and Transporting All Waste Categories

#	Assumption
1	Waste & container data obtained from OPG 00216-REP-03902-00003, Rev. 3.
2	Assume 90% are Type IP-2 and 10% are Type A shipments.
3	Assume 2 shipments/day to keep pace with planned waste retrieval.
4	Assume sufficient quantities for each packaging type to meet shipping rate for each distance. Some additional packaging units are included
	to advance load/test/stag the next packages to meet shipping rate.
5	Assume legal size/weight shipments are 24 hrs./day 5 days/week unrestricted.
6	This waste stream estimate excludes site labor & site equip. common to all wastes streams, e.g., cranes, forklifts, etc. These are added to total estimate for all waste streams.
7	Uncertainty adjustment factor includes an allowance for waste/packaging variations, trucking delays/interruptions,
	adverse weather & other risks which compound with distance.
8	Assume oversized shipments are 8 hrs./day rather than 24 hrs./day to account for restrictions. Round trip duration and costs adjusted accordingly.
9	Assume 70% Type B and 30% Type A.
10	Assume Trillium flask is already CNSC Type B certified. Assume 5 total CNSC transport certification renewals (1 every 5 years).
11	Assume new CNSC Type B certification. Regulatory testing limited to 1/4 scale impact limiter drop tests only.
12	Assume 5 total CNSC transport certification renewals (1 every 5 years).

4. Indicative Total Cost Estimate

This section describes the approach used to develop the total estimated cost to package the entire L&ILW inventory for transportation, and to road transport these packages from the WWMF to the alternate location, consistent with the assumptions and basis described elsewhere in the report. The associated total cost is estimated for four alternate location distances including the 100 km and 300 km distances for initiation of transports in 2045, and the 200 km and 2,000 km distances for initiation of transports in 2055. The total project cost includes the combination of waste category-specific costs estimated in Section 3, and the equipment and operational costs for the WWMF and alternate location that are common to all waste categories which are estimated in this section.

As described in Section 1, these cost estimates are considered high-level indicative AACE International Class 5 estimates. A high level top-down lump-sum costing methodology based on similar past projects, operational experience, a knowledge of the requirements and level of effort required, and aggregate unit rates are used to develop an indicative total cost estimate, consistent with Class 5 estimating practices.

4.1 Assumptions and Basis

4.1.1 *Assumptions*

The following assumptions are made to develop the estimated costs that are common to all waste categories and the waste category-specific estimated costs described in Section 3 which are combined to obtain the total estimated project cost for each of the four alternate location transport distances:

1. The estimates include all labour, material, and other direct costs (ODCs) for manufacturing and delivery of the transport packagings in the quantities needed for each waste category. It also includes packaging-specific support equipment such as equipment needed for waste container transfer, e.g. a shielding bell (if applicable), package-specific lifting fixtures (if applicable), etc. It is assumed that the empty transport packagings are delivered to the WWMF, and that the packaging-specific support equipment sets are delivered to both the WWMF and alternate location in the quantities required to support operations at the respective site. At the WWMF the empty transport packagings are prepared for loading and the packaging-specific support equipment is readied for operation at both sites.
2. The estimate is based on the sequence and timeline for packaging and transporting each waste category in its entirety in a continuous campaign as shown in Figure 3-2 and Figure 3-3, which is aligned with waste category retrieval as described in Section 3.1. The transport packages are transported from the WWMF at a rate that keeps pace with retrieval of each waste category from interim storage at the WWMF. The waste categories are retrieved and transport sequentially, one waste category and then the next, except that the LLSB waste containers are retrieved and transported in parallel with other waste categories. The average shipping rate needed to keep pace with retrievals across all waste categories is determined to be 2 (two) shipments per day, irrespective of transport distance.
3. It is assumed that the following WWMF resources and operations that occur prior to transport packaging and road transport operations are not included in this estimate since they are not considered incremental. These resources and operations would need to be

provided/performed irrespective of the DGR's location in accordance with OPG's planned activities at the Bruce Nuclear site described in Section 1:

- All facilities, resources and equipment needed to conduct ongoing waste management operations at the WWMF including receipt of waste from the plants and interim storage.
- The supply and loading of LLW containers for repackaging bulk waste or overpacking existing waste containers, e.g. LLSB and trench waste to render them DGR-ready.
- Waste retrieval operations consistent with OPG's planned activities at the Bruce Nuclear site.

4. The retrieval, packaging and transport of all L&ILW from the WWMF to the alternate location is estimated to take 30+ years to complete in a sequential and continuous campaign for the first 25 years as shown in Figure 3-2 and Figure 3-3, with the out-year shipment of RWCs commencing a bit later consistent with the planned waste retrieval schedule as described in Section 3.1. The duration and sequence of activities for each period or phase of transport packaging and road transport are assumed to be as follows:
   - Six (6) months for mobilization including installation of the transport packaging support equipment at the WWMF and alternate location.
   - Sequential retrieval, packaging and transport of each waste category during the respective time periods shown in Figure 3-2 and Figure 3-3, irrespective of transport distance. The level of road transport resources, i.e., tractor/trailers and drivers, needed to facilitate the planned shipping rate are determined accordingly for each of the four transport distances.
   - Three (3) months for demobilization.
5. A Project Manager (PM), based in the home office, and other project support personnel, e.g., for logistical planning and scheduling, resources to facilitate transport packaging and equipment supplies, etc. are assigned to each site to coordinate packaging, road transportation, and off-loading operations.
6. The following labour resources are assigned to the WWMF to perform transport packaging installation operations:
   - Waste Manager (1)
   - Shipping Broker (1)
   - Radiation Specialist (2)
   - Equipment Operator (1)
   - Labourer (2)
   - Crane Operator (1)
   - Rigger (1)
7. The following labour resources are assigned to the alternate location to perform transport packaging off-loading operations:
   - Waste Manager (1)

- Radiation Specialist (2)
- Equipment Operator (1)
- Labourer (2)
- Crane Operator (1)
- Rigger (1)

8. Given the relative future timeframe of such a project and the need for dedicated resources for long periods of time, it is assumed that new capital equipment, including transport packagings and support equipment in the quantities needed to complete the transports of each waste category, are purchased rather than assuming that existing resources will be available at that time. Conversely, the fleet of rolling stock, i.e., tractor/trailers of various types, and the driver resource pool, are assumed to be rented/leased and brokered from multiple local commercial providers of trucking services so that they can be scaled up or down as needed for a particular waste category shipment and to maintain the required rate of shipments.
9. The common equipment utilized for transport packaging operations at both the WWMF and the alternate location is assumed to be purchased at the beginning of the project. The same major equipment is assumed to be used and maintained for the duration of all waste category transports. It is assumed that 60% of the common equipment for each site will need to be replaced over the 30+ year duration of the project. This equipment includes:
   - An insulated, fabric covered, temporary building (100 ft. x 50 ft.) erected at the WWMF to enable transport packaging operations to occur indoors, irrespective of weather conditions. Roll-up doors, ventilation, and heating/cooling are provided. One fabric covered building is purchased for the site and utilized for the duration of the project. For the alternate location, the planned waste package receiving facility is assumed to be available for transport package unloading. It is assumed that this surface facility will have a crane with sufficient capacity to handle the various types of containers/components, transport overpacks/flasks and a shielded transfer bell (if applicable) that are needed for the various transport package off-loading operations.
   - A concrete pad at WWMF large enough to install the temporary fabric building, with a capacity sufficient for the weight of the containers and flasks set on the pad, and the transport equipment traffic in the building.
   - One yard crane, a heavy forklift and the lighter forklift are purchased for each site for the duration of the project. The cost of operation and maintenance of this equipment, and the associated consumable materials are included. The total cost for maintenance of common equipment for the sites is estimated at 5% of the equipment supply cost.
   - Radiological instruments are purchased to support transport packaging and off-loading operations. Annual instrument calibration is included.
   - Two shielded transfer bells, one for each site, are purchased for transferring unshielded resin liners to/from the associated transportation flasks.
10. It is assumed that the following DGR resources and operations that occur after transport package off-loading are not included in this estimate since they are not considered

incremental. These resources and operations would need to be provided/performed irrespective of the DGR's location in accordance with the OPG's planned activities at the Bruce Nuclear site described in Section 1:

- Facilities or overpack containers that may be required for temporary storage of waste containers/components awaiting DGR emplacement.
- Supplemental disposal packaging as may be required to render a waste container/component DGR-ready for emplacement.
- All facilities, resources and equipment needed to conduct DGR emplacement operations.

11. To the maximum extent for all waste categories, suitable transportation overpacks/flasks are assumed to be already designed and available from commercial sources. The cost for design of these "off-the-shelf" transport packagings is not included in the estimate, however, the cost for procurement of these is included. In cases where a unique or custom transport packaging is required for a particular waste category, the cost for design of "one-of-a-kind" packagings is included in the estimate as are the cost for procurement. Similarly the cost for modifications to the design of standard packagings is included as may be required as are the cost for procurement. The cost for CNSC licencing of Type B packagings per the transportation regulations for both existing and new packaging designs is included in the estimate. The cost for licence renewal for existing designs is included because of the relatively short term of a transport certifications and renewal every 5 years, compared with the long duration of the project.
12. As described in Sections 2 and 3, the proportion of Type IP-2 and Type A shipments for LLW and Type A and Type B shipments for ILW are assumed as follows:
    - 90% of the LLW inventory is assumed to be Type IP-2 shipments. The remaining 10% of the LLW inventory is assumed to be Type A shipments.
    - Generally multiple LLW containers are shipped in each Type IP-2 or Type A transport packaging which is legal size and weight. Conversely, intact or segmented LLW large components are generally shipped one per Type IP-2 or Type A transport packaging which may be legal size and weight or oversized and/or overweight.
    - 70% of the ILW inventory other than fuel channel waste is assumed to be Type B shipments. The remaining 30% of this ILW inventory is assumed to be Type A shipments. All fuel channel waste is assumed to be Type B except that 50% of the fuel channel waste already generated is assumed to be Type A.
    - A single ILW container is shipped in each Type B transport packaging. Some of these are legal size and weight, and some are oversized and/or overweight. One or more ILW containers are shipped in each Type A transport packaging. These are generally legal size and weight, but a few are oversized and/or overweight.
13. Road transportation operations are assumed to be a continuous 24/7 campaign for the durations of the project. The following are assumed for the estimate:
    - Both single and team drivers (two drivers in one truck eliminates the need to stop and rest) may be used, depending on the transport distance and the nature of the shipment,

e.g., unrestricted compliant shipments or restricted permitted shipments, whichever is optimal.

- The driver(s) leaves home base, picks up the load at the WWMF, transports it to the alternate location, returns the transport overpack/flask to the WWWF (if reusable), and picks up the next load and repeats the cycle or returns to home base.
- Driver(s) time at the WWMF for load pick-up and at L&ILW DGR for offloading is assumed to be four hours each.
- Drivers are home-based in Canada. No driver layover or hotel costs are included the trucking rates for shorter unrestricted shipments. Layover costs and hotel costs are included the trucking rates for longer restricted shipments.

14. The types, quantities, unit rates and assumptions used to develop the waste category-specific costs estimates are considered to be representative and based on commercial pricing. An adjustment factor to account for uncertainties and risks is applied to the waste category-specific total estimated cost as described in Section 3.2.
15. Manufacturers and suppliers located in Ontario, Canada are assumed to minimize delivery costs and avoid import duties for the significant quantities of containers, packagings, equipment and rolling stock needed for the project. Site labour resources located in Ontario Canada are assumed to minimize travel and living expenses and avoid relocation charges.

4.1.2 *Basis*

The following form the basis for developing the estimated cost for packaging and transporting the entire L&ILW inventory for the WWMF to the alternate location:

1. The estimate relies upon available waste category container and large component data, including the physical and radiological characteristics of the waste container or component as described in Section 2. Based on this waste category data, assumptions are made for the purpose of developing this estimate as discussed above and elsewhere in this report. The number of shipments for each waste category, and the road transport resources required to maintain the required shipment rate for each of the four transport distances are estimated as described in Section 3 and elsewhere in this report.
2. An average manloading approach with aggregate rates are used for estimating the cost of labour resources required to perform the transport packaging operations at the WWMF and unloading operations at the alternate location. More detailed estimating based on discrete task definitions is not used.
3. A level of effort method is used for estimating the cost of resources to provide management and supervision. The PM and project controls resources are assumed to be maintained at a fixed level for the duration of project.
4. The following paragraphs describe the major work activities that are anticipated for transport packaging, road transportation and off-loading for purposes of this estimate.

   Typical activities performed in preparation for project mobilization include:

- Engineering and quality assurance approval of the drawings and specifications for procurement of transport packagings and related equipment for each waste category.
- Select manufacturers, place purchase orders, purchase materials, fabricate and deliver the waste packagings and related equipment for each waste category.
- Oversight of manufacturing processes by Engineering and quality assurance personnel.
- Place purchase orders for yard crane, forklift, radiological instruments, fabric covered building, and concrete pad.
- Place purchase order for truck transport services.
- Complete detailed design of the “one-of-a-kind” transport packagings and CNSC licencing of both the “off-the-shelf and “one-of-a-kind” transport packagings.
- Prepare procedures and plans required to perform transport packaging operations on site.

Typical activities performed during the six (6) months project mobilization period include:

- Mobilize installation personnel to the WWMF and alternate location.
- Install concrete pad and assemble fabric covered building and support equipment on the pad at the WWMF.
- Start receiving new transport packagings and the related equipment from the manufacturers for the first waste categories to be shipped.
- Receive and commission the packaging-specific and common equipment at the WWMF and alternate location.
- Mobilize operations personnel to the WWMF and alternate location.
- Conduct site-specific and project-specific training.

Typical activities performed during the 30+ year period of packaging, transporting and off-loading the entire L&ILW inventory include:

- Continue receiving new empty containers and the related equipment at the WWMF from the manufacturers for the subsequent waste categories to be shipped.
- Coordinate preparation of transport package/waste manifests/documentation packages to facilitate shipment to the alternate location.
- Schedule/coordinate shipments with the truck transport service providers and the alternate location.
- Receive the waste containers/components to be shipped at the designated staging point at WWMF, transfer the container into or install the transport packaging, perform all pre-shipment surveys, tests, certifications, and inspections as required.
- Place and secure the transport packaging onto the truck transport conveyance, complete all radiological surveys as required, and finalize shipping papers and waste manifests.
- Transport the packages on public roads by truck to the alternate location.

- Receive and remove the transport packaging from the transport conveyance at the alternate location. Remove the waste container/component from the transport packaging.
- Turnover the waste containers/components at the designated staging point at the alternate location for subsequent disposition.
- Return transport of empty tractor/trailers and reusable transport packagings to the WWMF (if applicable), off-load at the WWMF, and repeat the cycle until all L&ILW is removed from the WWMF.

Typical activities performed during three (3) months project demobilization period include:

- Verify that all container/waste certificates/signed manifests and lifetime quality records are entered into the records system and turned over.
- Verify that the concrete pad and fabric covered building at the WWMF is radiologically clean. Turnover to WWMF site operations for re-purpose or dismantlement.
- Verify that the packaging-specific and common equipment are radiologically clean and demobilize them.
- Close out purchase orders and contracts.
- Demobilize personnel.

5. The cost estimates developed for each waste category as described in Section 3 are summed to obtain the combined cost for all waste categories. The cost for the supply of the common equipment, common equipment maintenance, consumable materials and labour at the WWMF and alternate location that are utilized for all waste categories are added to this combined cost to obtain the total cost. A management reserve is applied as described in Section 4.2.2 to obtain the indicative total estimate project cost.
6. The estimate does not include the cost for socioeconomic related activities for the affected provincial and local entities having jurisdiction along the transportation corridor. These include emergency response preparedness program development and implementation; initial and recurring first responder education, training and periodic simulation drills; new or augmented specialized facilities and equipment that may be needed; internal and external communication systems; and public outreach, stakeholder participation and economic assistance programs. These costs are anticipated to be proportional to transport distance and the associated population densities, and would include one-time initial and recurring annual costs.
7. The estimated costs are provided in 2016 Canadian dollars (CADs). Costs are not inflated, escalated, or discounted over the period of performance.
8. Costing is generally developed in CADs throughout. In instances where U.S. costing is used, the conversion rate from U.S. to Canadian dollars used for this estimate is 1 USD = 1.30 CAD.
9. The estimate does not include Canadian customs duties, Value Added Tax (VAT), sales tax, bonding, insurance or the capital cost of money. It also does not include other costs for OPG management and oversight.

4.2 Summary of Costs

Estimated costs are provided for the two alternate location host geologies and the two assumed transport distances for each as follows:

1. 100 km Transport: Alternate location in sedimentary rock located 100 km from the WWMF by road and available beginning in year 2045.
2. 300 km Transport: Alternate location in sedimentary rock located 300 km from the WWMF by road and available beginning in year 2045.
3. 200 km Transport: Alternate location in crystalline rock located 200 km from the WWMF by road and available beginning in year 2055.
4. 2,000 km Transport: Alternate location in crystalline rock located 2,000 km from the WWMF by road and available beginning in year 2055.

The cost for transport packaging supply and for packaging operations performed at the WWMF and the off-loading operations performed at the alternate location are the same for all transport distances, accounting for the slightly larger L&ILW inventory for the year 2055 availability scenario compared with the year 2045 availability scenario. Table 4-1 summarizes the total cost (in 2016 CAD) for packaging, transporting and off-loading the entire L&ILW inventory from the WWMF to the alternate location, for the above four transport distance scenarios. The total estimated cost includes the costs for each waste category summarized in Section 3 which are summed to obtain the combined cost for all waste categories, plus the costs associated with operations performed at the WWMF and alternate location that are common to all waste categories as described in Section 4.1. The indicative total project cost by distance for the sedimentary rock 2045 availability scenario is shown graphically in Figure 4-1 which shows that the total project cost ranges from $382 million to $493 million for the shortest 100 km to the longest 300 km alternate location transport distances. Similarly, the indicative total project cost by distance for the crystalline rock 2055 availability scenario is shown graphically in Figure 4-2 which shows that the total project cost ranges from $452 million to $1.4 billion for the shortest 200 km to the longest 2,000 km alternate location transport distances.

Table 4-1: Indicative Total Project Cost for L&ILW Packaging and Transport to Alternate Location by Distance (in 2016 CAD)

Geology/Year Transports Initiated	One-Way Distance by Road (km)	Waste Container/ Component Quantities	Number of Road Shipments and Round Trips	Total Project Cost ($K)
Sedimentary 2045	100	53,851	11,338	**$381,801**
Sedimentary 2045	300	53,851	11,338	**$493,081**
Crystalline 2055	200	57,321	11,992	**$451,719**
Crystalline 2055	2,000	57,321	11,992	**$1,424,370**

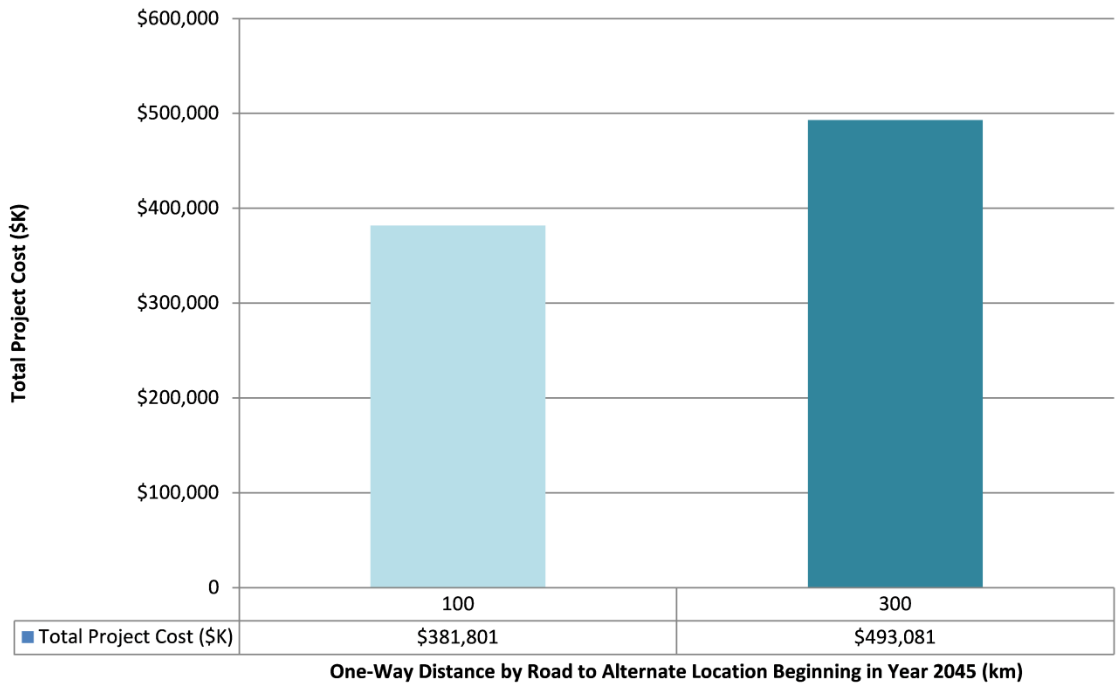


Figure 4-1: Indicative Total Project Cost for L&ILW Packaging and Transport to Alternate Location by Distance for 2045 Availability (2016 CAD $K)

Figure 4-2: Indicative Total Project Cost for L&ILW Packaging and Transport to Alternate Location by Distance for 2055 Availability (2016 CAD $K)

4.2.1 *Total Cost by Waste Category and Cost Category*

The total cost by cost category for packaging, transporting and off-loading the entire L&ILW inventory from the WWMF to the alternate location for the sedimentary rock 2045 availability scenario with 100 km and 300 km transport distances are provided in Table 4-2 and Table 4-3. Similarly, the total cost by cost category for the alternate location crystalline rock 2055 availability scenario with 100 km and 300 km transport distances are provided in Table 4-4 and Table 4-5. The total costs are shown graphically by waste category and cost category in Figure 4-3 and Figure 4-4. As Figure 4-3 indicates, the cost for packaging and transporting the LLSB waste containers to the alternate location is the largest compared with all other waste categories. As Figure 4-4 indicates, road transport costs begin to dominate other costs as the transport distance to the alternate location increases, whilst site costs remain essentially constant.

Table 4-2: Total Cost for Alternate Location 2045 Availability 100 km Transport by Waste and Cost Categories (2016 CAD $K)

Waste Category	Descriptor	Waste Container/ Component Quantities	Number of Shipments	Bulk Waste Repackaging Container Supply Cost	Transport Packaging Supply Cost	Packaging Specific Equipment Cost	Packaging Specific Maintenance Cost	Truck Transport Cost	Total Waste Category Cost
Low Level Waste Categories Packaging and Truck Transport									
LLSB Waste Containers	DGR & not DGR Ready	47,332	6,834	$0	$1,034	$112	$54	$13,216	$15,858
Bruce Steam Generators	Self-Packaged Segments	416	416	$0	$1,987	$65	$28	$1,245	$3,657
Trench Waste	In Unshielded Containers	1,926	241	$0	$452	$112	$27	$466	$1,162
Heat Exchangers	Intact & Segmented	51	51	$0	$1,011	$65	$49	$99	$1,346
	Subtotal LLW:	49,725	7,541	$0	$4,933	$389	$173	$16,528	$22,023
Intermediate Level Waste Categories Packaging and Truck Transport									
IC-2 Tile Hole Liner Waste (fixed liners)	In Shielded Containers	17	17	$1,700	$1,799	$44	$118	$36	$3,697
IC-2 Tile Hole Liner Waste (remov. liners)	In Shielded Containers	66	66	$6,567	$1,799	$44	$118	$140	$8,668
Quadricell Resin Liners	Unshielded Liners	115	98	$0	$2,288	$396	$133	$208	$3,025
Resin Liners (IC-12/IC-18)	Unshielded Liners	2,083	1,771	$0	$2,288	$396	$133	$3,767	$6,584
IC-18 Tile Hole Equiv. Liner Waste	In Shielded Containers	616	616	$63,901	$1,881	$46	$123	$1,370	$67,321
IC-2 Grouted Tile Hole Liners	Intact Self-Shielded	43	43	$0	$7,207	$132	$274	$124	$7,736
Bruce RWCs (Units 1&2 and 3-8)	Shielded Robust	712	712	$0	$13,175	$138	$0	$2,390	$15,703
Darlington RWCs (Units 1-4)	Shielded Transportable	474	474	$0	$75	$132	$15	$1,008	$1,230
	Subtotal ILW:	4,126	3,796	$72,167	$30,511	$1,328	$914	$9,044	$113,964
Subtotal All L&ILW Waste Categories:		53,851	11,338	$72,167	$35,445	$1,717	$1,087	$25,572	$135,988
								Mobilization/Demobilization Labour:	$6,398
								Site Operations Labour:	$173,701
								Site Common Equipment Supply:	$7,570
								Consumable Materials:	$10,140
								Site Common Equipment Maintenance:	$7,097
								Subtotal Site Equipment and Labour:	$204,906
								Subtotal Packaging, Truck Transport, Site Equipment & Labour All Waste Categories:	$340,894
								Prudent Management Reserve (@12%):	$40,907
								Total Estimated Cost All Waste Categories:	**$381,801**

Table 4-3: Total Cost for Alternate Location 2045 Availability 300 km Transport by Waste and Cost Categories (2016 CAD $K)

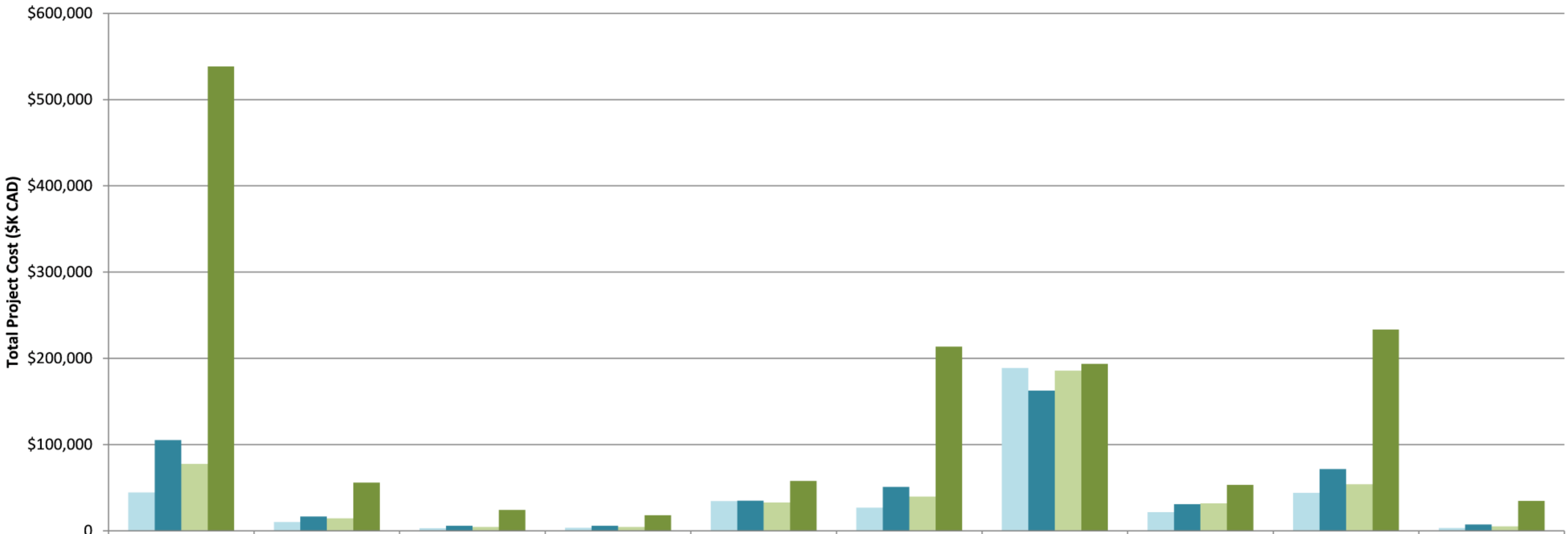
Waste Category	Descriptor	Waste Container/ Component Quantities	Number of Shipments	Bulk Waste Repackaging Container Supply Cost	Transport Packaging Supply Cost	Packaging Specific Equipment Cost	Packaging Specific Maintenance Cost	Truck Transport Cost	Total Waste Category Cost
Low Level Waste Categories Packaging and Truck Transport									
LLSB Waste Containers	DGR & not DGR Ready	47,332	6,834	$0	$2,009	$112	$103	$39,648	$50,246
Bruce Steam Generators	Self-Packaged Segments	416	416	$0	$2,959	$65	$76	$3,579	$8,015
Trench Waste	In Unshielded Containers	1,926	241	$0	$875	$112	$48	$1,397	$2,918
Heat Exchangers	Intact & Segmented	51	51	$0	$1,922	$65	$94	$296	$2,853
	Subtotal LLW:	49,725	7,541	$0	$9,318	$424	$386	$53,904	$64,032
Intermediate Level Waste Categories Packaging and Truck Transport									
IC-2 Tile Hole Liner Waste (fixed liner)	In Shielded Containers	17	17	$1,871	$3,249	$48	$257	$118	$5,543
IC-2 Tile Hole Liner Waste (remov. liner)	In Shielded Containers	66	66	$7,180	$3,249	$48	$257	$460	$11,193
Quadricell Resin Liners	Unshielded Liners	115	98	$0	$4,963	$432	$268	$681	$6,344
Resin Liners (IC-12/IC-18)	Unshielded Liners	2,083	1,771	$0	$4,963	$432	$268	$12,327	$17,990
IC-18 Tile Hole Equiv. Liner Waste	In Shielded Containers	616	616	$69,474	$3,384	$50	$268	$4,468	$77,643
IC-2 Grouted Tile Hole Liners	Intact Self-Shielded	43	43	$0	$13,693	$144	$590	$405	$14,833
Bruce RWCs (Units 1&2 and 3-8)	Shielded Robust	712	712	$0	$26,526	$150	$0	$7,526	$34,202
Darlington RWCs (Units 1-4)	Shielded Transportable	474	474	$0	$103	$144	$19	$3,300	$3,566
	Subtotal ILW:	4,126	3,796	$78,524	$60,128	$1,448	$1,928	$29,285	$171,313
Subtotal All L&ILW Waste Categories:		53,851	11,338	$78,524	$69,446	$1,872	$2,313	$83,189	$235,345
								Mobilization/Demobilization Labour:	$6,398
								Site Operations Labour:	$173,701
								Site Common Equipment Supply:	$7,570
								Consumable Materials:	$10,140
								Site Common Equipment Maintenance:	$7,097
								Subtotal Site Equipment and Labour:	$204,906
								Subtotal Packaging, Truck Transport, Site Equipment & Labour All Waste Categories:	$440,251
								Prudent Management Reserve (@12%):	$52,830
								Total All Waste Categories:	**$493,081**

Table 4-4: Total Cost for Alternate Location 2055 Availability 200 km Transport by Waste and Cost Categories (2016 CAD $K)

Waste Category	Descriptor	Waste Container/ Component Quantities	Number of Shipments	Bulk Waste Repackaging Container Supply Cost	Transport Packaging Supply Cost	Packaging Specific Equipment Cost	Packaging Specific Maintenance Cost	Truck Transport Cost	Total Waste Category Cost
Low Level Waste Categories Packaging and Truck Transport									
LLSB Waste Containers	DGR & not DGR Ready	50,514	7,231	$0	$1,522	$112	$79	$27,971	$34,135
Bruce Steam Generators	Self-Packaged Segments	416	416	$0	$3,445	$65	$100	$1,944	$6,388
Trench Waste	In Unshielded Containers	1,926	241	$0	$663	$112	$37	$931	$2,006
Heat Exchangers	Intact & Segmented	51	51	$0	$1,467	$65	$72	$197	$2,070
	Subtotal LLW:	52,907	7,939	$0	$8,161	$407	$331	$35,700	$44,599
Intermediate Level Waste Categories Packaging and Truck Transport									
IC-2 Tile Hole Liner Waste (fixed liners)	In Shielded Containers	17	17	$1,785	$2,497	$46	$185	$76	$4,588
IC-2 Tile Hole Liner Waste (remov. liners)	In Shielded Containers	66	66	$6,873	$2,497	$46	$185	$294	$9,894
Quadricell Resin Liners	Unshielded Liners	115	98	$0	$3,574	$414	$198	$435	$4,621
Resin Liners (IC-12/IC-18)	Unshielded Liners	2,289	1,946	$0	$3,574	$414	$198	$8,655	$12,841
IC-18 Tile Hole Equiv. Liner Waste	In Shielded Containers	698	698	$75,550	$2,606	$48	$193	$3,240	$81,636
IC-2 Grouted Tile Hole Liners	Intact Self-Shielded	43	43	$0	$13,085	$138	$564	$259	$14,046
Bruce RWCs (Units 1&2 and 3-8)	Shielded Robust	712	712	$0	$19,606	$144	$0	$4,088	$23,838
Darlington RWCs (Units 1-4)	Shielded Transportable	474	474	$0	$89	$138	$17	$2,108	$2,352
	Subtotal ILW:	4,414	4,053	$84,207	$47,528	$1,388	$1,539	$19,153	$153,816
Subtotal All L&ILW Waste Categories:		57,321	11,992	$84,207	$55,689	$1,795	$1,870	$54,853	$198,415
								Mobilization/Demobilization Labour:	$6,398
								Site Operations Labour:	$173,701
								Site Common Equipment Supply:	$7,570
								Consumable Materials:	$10,140
								Site Common Equipment Maintenance:	$7,097
								Subtotal Site Equipment and Labour:	$204,906
								Subtotal Packaging, Truck Transport, Site Equipment & Labour All Waste Categories:	$403,321
								Prudent Management Reserve (@12%):	$48,398
								Total All Waste Categories:	**$451,719**

Table 4-5: Total Cost for Alternate Location 2055 Availability 2,000 km Transport by Waste and Cost Categories (2016 CAD $K)

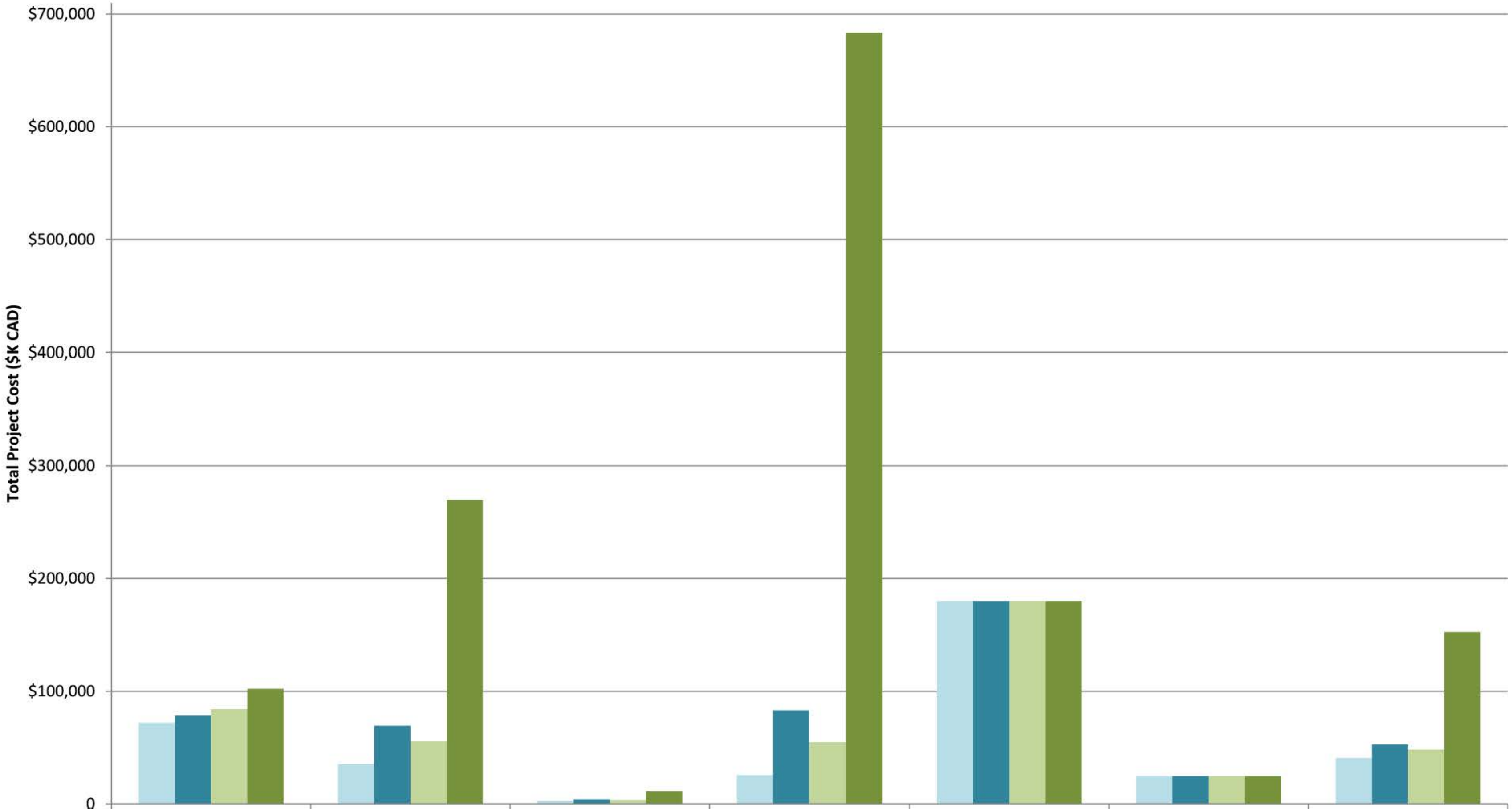
Waste Category	Descriptor	Waste Container/ Component Quantities	Number of Shipments	Bulk Waste Repackaging Container Supply Cost	Transport Packaging Supply Cost	Packaging Specific Equipment Cost	Packaging Specific Maintenance Cost	Truck Transport Cost	Total Waste Category Cost
Low Level Waste Categories Packaging and Truck Transport									
LLSB Waste Containers	DGR & not DGR Ready	50,514	7,231	$0	$7,855	$112	$395	$279,706	$403,295
Bruce Steam Generators	Self-Packaged Segments	416	416	$0	$5,389	$65	$198	$24,278	$41,901
Trench Waste	In Unshielded Containers	1,926	241	$0	$3,408	$112	$175	$9,312	$18,210
Heat Exchangers	Intact & Segmented	51	51	$0	$7,389	$65	$368	$1,973	$13,712
	Subtotal LLW:	52,907	7,939	$0	$33,658	$495	$1,589	$441,376	$477,118
Intermediate Level Waste Categories Packaging and Truck Transport									
IC-2 Tile Hole Liner Waste (fixed liners)	In Shielded Containers	17	17	$2,294	$12,791	$56	$1,200	$921	$17,263
IC-2 Tile Hole Liner Waste (remov. liners)	In Shielded Containers	66	66	$8,488	$12,791	$56	$1,200	$3,574	$26,110
Quadricell Resin Liners	Unshielded Liners	115	98	$0	$23,054	$504	$1,176	$5,293	$30,028
Resin Liners (IC-12/IC-18)	Unshielded Liners	2,289	1,946	$0	$23,054	$504	$1,176	$105,361	$130,095
IC-18 Tile Hole Equiv. Liner Waste	In Shielded Containers	698	698	$91,415	$13,248	$58	$1,243	$39,148	$145,112
IC-2 Grouted Tile Hole Liners	Intact Self-Shielded	43	43	$0	$35,091	$168	$1,645	$3,152	$40,055
Bruce RWCs (Units 1&2 and 3-8)	Shielded Robust	712	712	$0	$115,720	$174	$0	$59,033	$174,927
Darlington RWCs (Units 1-4)	Shielded Transportable	474	474	$0	$272	$168	$37	$25,668	$26,145
	Subtotal ILW:	4,414	4,053	$102,197	$236,022	$1,688	$7,677	$242,150	$589,734
Subtotal All L&ILW Waste Categories:		57,321	11,992	$102,197	$269,680	$2,183	$9,267	$683,526	$1,066,853
						Mobilization/Demobilization Labour:			$6,398
						Site Operations Labour:			$173,701
						Site Common Equipment Supply:			$7,570
						Consumable Materials:			$10,140
						Site Common Equipment Maintenance:			$7,097
						Subtotal Site Equipment and Labour:			$204,906
				Subtotal Packaging, Truck Transport, Site Equipment & Labour All Waste Categories:					$1,271,759
						Prudent Management Reserve (@12%):			$152,611
						Total All Waste Categories:			**$1,424,370**



	LLSB Waste Containers	Bruce Steam Generators	Trench Waste	Heat Exchangers	IC-2 Tile Hole Liners	Resin Liners	Tile Hole Equiv. Liner	Grouted Tile Hole Liners	Bruce RWCs	Darlington RWCs
100km	$44,524	$10,267	$3,263	$3,778	$34,716	$26,978	$189,011	$21,720	$44,087	$3,454
300km	$105,273	$16,793	$6,113	$5,977	$35,063	$50,983	$162,674	$31,077	$71,658	$7,471
200km	$77,714	$14,542	$4,566	$4,714	$32,972	$39,754	$185,856	$31,978	$54,269	$5,354
2,000km	$538,445	$55,942	$24,312	$18,307	$57,907	$213,783	$193,741	$53,479	$233,547	$34,906

Waste Catregory

Figure 4-3: Total Cost L&ILW Packaging, Transport and Off-Loading by Waste Category (2016 CAD $K)



	Repackaging Bulk Waste Containers	Transport Packaging	Packaging-Specific Equipment	Truck Transport	Site Labor	Site Equipment	Management Reserve
100km	$72,167	$35,445	$2,804	$25,572	$180,099	$24,807	$40,907
300km	$78,524	$69,446	$4,186	$83,189	$180,099	$24,807	$52,830
200km	$84,207	$55,689	$3,665	$54,853	$180,099	$24,807	$48,398
2,000km	$102,197	$269,680	$11,450	$683,526	$180,099	$24,807	$152,611

Cost Category

Figure 4-4: Total Cost for L&ILW Packaging, Transport and Off-Loading by Cost Category (2016 CAD $K)

4.2.2 *Explanation of Cost Categories*

Table 4-2 through Table 4-5 provide cost breakdown categories which are defined as follows:

1. *Bulk Waste Repackaging Container Supply Cost:* This includes the cost for procurement, fabrication, and delivery of new waste containers for repackaging bulk waste retrieved from WWMF interim storage systems that could be rendered L&ILW DGR-ready in their current form, but they cannot be rendered transportable in their current form by efficient means. Such bulk waste is repackaged in containers that are both transportable and L&ILW DGR-ready. This includes the IC-2 Fixed Tile Hole Liner Waste, the IC-2 Removable Tile Hole Liner Waste, and the IC-18 Tile Holes Equivalent Liner Waste. The liners for these storage systems are long slender open-ended tubes that contain a broad range of bulk ILW in various forms. The respective bulk waste is assumed to be repackaged in shielded containers that are transportable as a Type A packaging or overpacked in a Type B packaging configuration, as described in Section 2.3.
2. *Transport Packaging Supply Costs:* This includes the cost for procurement, (including fabrication and delivery), of suitable transportation packagings for waste containers and large components retrieved from interim storage that are not transportable in their current form. These include unshielded LLW containers, intact or segmented large component SCOs, unshielded ILW resin liners, repackaged or grouted tile hole ILW and ILW in shielded RWCs. The transportation packagings supplied for these waste categories include Type IP-2 freight containers for overpacking LLW containers, Type A freight containers for overpacking LLW and ILW containers, Type IP-2 supplemental soft packagings for self-packaged SCOs, shielded Type B flasks for unshielded ILW liners, and unshielded Type B overpacks for shielded ILW containers, as described in Section 2.3. The quantity of transport packagings required increases with increasing transport distance, as described in Section 3.1.
3. *Packaging-Specific Equipment Supply Cost:* This includes the cost for procurement, (including fabrication and delivery), of the support equipment needed for loading, transferring, lifting, handling supporting, securing and off-loading the various transportation packagings used for each waste category at the WWMF and the alternate location. As indicated in Section 3.2 under Section C, these include lift fixtures and riggings for waste containers, large components and transport packages; shielded transfer bells for transferring unshielded liners to shielded transport flasks; support frames, cribbings, tie-downs and binders for securing the transport packages to the truck transport conveyance per regulations.
4. *Packaging-Specific Maintenance Cost:* This includes the cost to maintain the reusable transport packaging systems and packaging-specific equipment as described in Section 3.2 under Section F. Such costs include periodic inspections, maintenance and repairs for reusable Type IP-2, Type A and Type B transport packagings. For Type B transport packagings it also includes annual leak testing and licence renewal every five years per the CNSC transport regulations, as described in Item 11 of Section 4.1.1. Also included are the cost to maintain the packaging-specific equipment described in Item 3 above.
5. *Truck Transport Cost:* This includes the cost for the fleet of tractor/trailers of various types and the tractor/trailer drivers in sufficient quantities to conduct road transport operations as

described in Section 4.1. It also includes the cost for consumables, e.g., fuel, tractor/trailer periodic maintenance, permitting fees for oversized and/or overweight shipments, escort vehicle services (as necessary), and other ODCs such a travel and living expenses associated with longer distances and/or restricted truck transport operations.

6. *Mobilization/Demobilization Cost:* For project mobilization, this includes the labour costs for the initial procurement of transportation packagings and equipment, deployment of resources to the WWMF and alternate location, and preparations to commence site operations, as in Section 4.1.2 under Item 4. For project demobilization, this includes final radiation surveys on the sites, decommissioning of equipment, turnover of lifetime records, and demobilizing personnel at the WWMF and alternate location, as described in Section 4.1.2 under Item 4.
7. *Site Operations Labour Cost:* This includes the cost for the site labour resources needed to support transport packaging and loading operations at the WWMF, and transport package off-loading operations at the alternate location, as described in Section 4.1. It also includes home office project management and project controls labour resources, other general and administrative services for health and safety, quality assurance, ongoing procurement, regulatory compliance, etc., and the related ODCs such travel and living expenses.
8. *Site Common Equipment Supply Cost:* This includes the cost of equipment that is common to all waste categories that is needed to support transport packaging and loading operations at the WWMF, and transport package off-loading operations at the alternate location, as described in Section 4.1.
9. *Site Common Equipment Maintenance Cost:* This includes the cost to maintain the common equipment utilized at the WWMF and alternate location to support transport packaging operations as described in Section 4.1.1 under Item 9 for the duration of the project. Such costs include periodic inspections, maintenance and repairs of this equipment which is utilized for all waste categories.
10. *Consumable Materials Cost:* This includes the cost of consumable materials for reusable transport packagings, packaging-specific equipment and site common equipment. Such consumable materials include fuels, lubricants, gaskets, seals, standard fasteners, protective equipment materials, health physics materials, etc.
11. *Management Reserve Cost:* A management reserve is applied to the total cost to provide a prudent allowance for unanticipated and unplanned but necessary additional work needed to complete the project, given its future timeframe and the range of unknowns at this early conceptual stage. These include additional materials, equipment, and labour resources; extended delays, work stoppages and rework; onerous regulatory changes and oversight, extraordinary working conditions, performance payment delays, etc. Given the magnitude, complexity and long duration of the project, a management reserve of 12% is considered appropriate.

The costs for Items 3 and 4, Items 6 and 7, and Items 8 through 10 are combined for graphical clarity in Figure 4-4.

4.2.3 *Metrics*

A sampling of metrics for packaging, transporting and off-loading the L&ILW inventory from the WWMF to the alternate location is provided in Table 4-6.

Table 4-6: Metrics for Alternate Location Packaging, Transport and Off-Loading

Parameter Metric	Alternate Location Distance by Road			
	100 km	**300 km**	**200 km**	**2,000 km**
LLW Volume (m^3)	138,589	138,589	146,544	146,544
% LLW Volume	*93%*	*93%*	*93%*	*93%*
ILW Volume (m^3)	10,155	10,155	10,989	10,989
% ILW Volume	*7%*	*7%*	*7%*	*7%*
Total L&ILW Volume (m^3)	**148,744**	**148,744**	**157,532**	**157,532**
Number of LLW Shipments	7,542	7,542	7,939	7,939
% LLW Shipments	*67%*	*67%*	*66%*	*66%*
Number of ILW Shipments	3,796	3,796	4,053	4,053
% ILW Shipments	*33%*	*33%*	*34%*	*34%*
Number Legal Size/Weight Shipments	10,147	10,147	10,801	10,801
% Legal Size & Weight Shipments	*89%*	*89%*	*90%*	*90%*
Number Oversized/Overweight Shipments	1,191	1,191	1,191	1,191
% Oversized/Overweight Shipments	*11%*	*11%*	*10%*	*10%*
Total Number Shipments	**11,338**	**11,338**	**11,992**	**11,992**
Number Different Packaging Types/Models	14	14	14	14
Quantity Standard Packagings	739	779	846	1,072
% Standard Packagings	*62%*	*62%*	*64%*	*63%*
Quantity Custom Packagings	447	478	467	635
% Custom Packagings	*38%*	*38%*	*36%*	*37%*
Quantity Reusable Packagings	71	142	115.5	510
% Reusable Packagings	*6%*	*11%*	*9%*	*30%*
Quantity One-Time Use Packagings	1,115	1,115	1,197	1,197
% One-Time Use Packagings	*94%*	*89%*	*91%*	*70%*
Total Number Packagings Supplied	**1,186**	**1,257**	**1,313**	**1,707**
Number of Trucks Needed	36	72	54	283
Total Distance Traveled (km)	2,267,515	6,802,545	4,796,970	47,969,700
Total Fuel Consumed (litres)	220,432	661,295	466,042	4,660,424