APM Conceptual Design and Cost Estimate for a Deep Geological Repository in Crystalline Rock

Summary Report

APM-REP-00440-0011 October 2011

Nuclear Waste Management Organization

nwmo
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EXECUTIVE SUMMARY

The Nuclear Waste Management Organization (NWMO) is implementing Adaptive Phased Management (APM), Canada's plan for the long-term management of its used nuclear fuel. The APM approach includes centralized containment and isolation of used nuclear fuel in a deep geological repository constructed within a suitable host rock formation such as crystalline rock or sedimentary rock. APM also includes a used fuel transportation system.

From 2009 to 2011, NWMO and SNC-Lavalin updated the previous conceptual design and cost estimate for the APM deep geological repository in crystalline rock prepared by CTECH and updated the conceptual design and cost estimate for the APM used fuel transportation system prepared by Cogema. The cost estimating activities for the APM update were allocated as follows:

1. NWMO was responsible for estimating APM costs for siting, design development, safety assessment, licensing, approvals, program management and related support to APM facility construction, operation, decommissioning and closure.

2. SNC-Lavalin was responsible for estimating APM costs for final design, construction, operation, extended monitoring, decommissioning and closure of the APM facility, and for the used fuel transportation system.

Two used nuclear fuel inventory scenarios are considered in the APM cost analysis for long-term management. The Base Case assumes 3.6 million used CANDU fuel bundles and the Alternate Case assumes 7.2 million used CANDU fuel bundles.

Methodology

For each case, the scope of the APM project was systematically divided into separate areas of effort to create a project Work Breakdown Structure (WBS).

The Level 2 WBS for NWMO's input to the APM cost estimate is identified as:

- 05 - Building Relationships
- 10 - Adapting to Change
- 15 - Siting
- 20 - Design Development & Safety Case
- 25 - Research & Confidence Building
- 30 - Site Verification & Licence Support
- 40 – Facility Design & Construction
- 45 – Facility Operation
- 55 – Environmental Assessment & Monitoring
- 60 – Decommissioning & Closure
- 90 - Common Services

The WBS components are scheduled in project years. Year 01 is 2010. Estimated costs are stated in constant 2010 Canadian dollars.

Estimated APM Costs

The previous cost estimate for an APM deep geological repository and used fuel transportation system for 3.6 million used CANDU fuel bundles was $16.9 billion (2010$), with a present value of $6.9 billion (2010$). This cost estimate was prepared by CTECH and Cogema Logistics in 2003 with input from Ontario Power Generation. This estimate was further reviewed and accepted by the NWMO for use in financial planning for long-term management of Canada's used nuclear fuel.

In 2009, NWMO contracted SNC-Lavalin Nuclear to update the APM conceptual design and cost estimate for a used fuel deep geological repository and transportation system. The 2011 reference APM cost estimate for 3.6 million used CANDU fuel bundles is $17.9 billion (2010$), with a present value of $7.0 billion (2010$).

A summary variance analysis for changes from the previous APM cost estimate prepared in 2003 and the current reference APM cost estimate prepared in 2011 is as follows:

APM Cost Estimate (3.6 million used CANDU fuel bundles)	**2010$ ($ billion)**	**2010$ PV ($ billion)**
2003 estimate	**16.9**	**6.9**
Higher cost for "in-floor" placement of containers	1.1	
Higher siting and engagement costs	0.5	
Lower development costs after obtaining Construction Licence	(0.3)	
Lower transportation costs (mostly labour)	(0.3)	
Lower costs for facility decommissioning	(0.2)	
Lower DGR operating labour rates	(0.4)	
Other change	0.1	
Additional contingency	0.5	
2011 estimate	**17.9**	**7.0**

The APM cost estimate includes allowances and contingencies which, on an aggregate basis, are 29% of the total estimate.

The increase in total lifecycle cost is due primarily to changes in mine design assumptions and placement method for used fuel containers. The smaller increase in present value costs is due to an overall cost decrease in labour and associated reduction in escalated costs.

The APM cost estimate for the Base Case inventory of 3.6 million used CANDU fuel bundles is $17.9 billion (2010$). The APM cost estimate for the Alternate Case inventory of 7.2 million used CANDU fuel bundles is $29.3 billion (2010$). To calculate the APM cost estimate for a used fuel inventory between 3.6 million and 7.2 million used CANDU fuel bundles, a straight line interpolation should be used.

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1. INTRODUCTION

The Nuclear Waste Management Organization (NWMO) is implementing Adaptive Phased Management (APM), Canada's plan for the long-term management of its used nuclear fuel. The APM approach includes centralized containment and isolation of used nuclear fuel in a deep geological repository constructed within a suitable host rock formation (see Figure 1 for an illustration of an APM deep geological repository in crystalline rock). APM also includes a used fuel transportation system.

From 2009 to 2011, NWMO and SNC-Lavalin updated the previous conceptual design and cost estimate for the APM deep geological repository (DGR) prepared by CTECH (2002; 2003) and for the APM used fuel transportation system prepared by Cogema Logistics (2003a; 2003b). The cost estimating activities for the APM update were allocated as follows:

a) NWMO was responsible for estimating APM costs for siting, design development, safety assessment, licensing, approvals, program management and related support to APM facility construction, operation, decommissioning and closure (NWMO 2011).

b) SNC-Lavalin was responsible for estimating APM costs for final design, construction, operation, extended monitoring, decommissioning and closure of the APM facility (SNC-Lavalin 2011a; 2011b) and for the used fuel transportation system (SNC-Lavalin 2011c; 2011d).

2. PURPOSE OF THE COST ESTIMATE

The purpose of the updated conceptual APM lifecycle cost and schedule estimate for a deep geological repository and associated used fuel transportation system is to allow NWMO to examine the financial implications of managing Canada's used nuclear fuel over the long term.

The APM design and cost estimate for a deep geological repository is currently at a concept level of development and has been prepared for financial planning purposes as part of the NWMO funding formula. It is not a project control estimate.

3. METHODOLOGY

This report is a summary of the updated APM cost estimate for a deep geological repository constructed in crystalline rock for the Base Case scenario of 3.6 million used CANDU fuel bundles prepared by NWMO (2011) and SNC-Lavalin (2011b; 2011d). These used fuel bundles are assumed to be produced at Canadian nuclear facilities owned by Ontario Power Generation Inc. (OPG), New Brunswick Power Nuclear (NBP), Hydro-Québec (HQ) and Atomic Energy of Canada Limited (AECL).

The cost estimate was prepared by subject matter experts based on a Work Breakdown Structure (WBS) (see Section 5), who reviewed and updated the Work Element Definition Sheets (WEDS) previously prepared by CTECH (2003) and Cogema Logistics (2003b).

Figure 1: APM Deep Geological Repository in Crystalline Rock

4. COST ESTIMATING ASSUMPTIONS

The APM cost estimate has been based on a number of high-level assumptions. Many of these assumptions are for financial planning purposes. Actual implementation of APM may differ substantially in terms of the scope of work and the timing of the activities. NWMO is committed to a stepwise decision-making process and will only proceed to the next step after careful consideration and with societal support.

In addition, it is noted that the site selection process is community-driven; NWMO must allow the time required for communities to engage in an informed and willing way in the different phases of site investigations. Many decisions, such as the nature and duration of monitoring, closure and postclosure monitoring are to be decided in collaboration with future societies.

To support cost estimation, the major APM reference planning assumptions are outlined below:

Table 1: Major Cost Estimating Assumptions

Siting	
1.	All APM technical development work will be completed by the time of construction of the APM deep geological repository. Demonstration of repository technology may occur in the Underground Demonstration Facility (UDF).
2.	APM technical work program activities will proceed in parallel with the schedule for APM siting to support advancement of the siting process, design development and the safety case for a used fuel deep geological repository.
3.	The cost estimate assumes the APM program will be continuous with no hold points or abnormal periods of inactivity whilst awaiting funding approvals, management reviews or licensing decisions. However, the cost estimate has assumed reasonable time periods for the completion of siting tasks.
4.	The design of the APM facility will accept and accommodate the total Canadian used nuclear fuel inventory of 3.6 million used CANDU bundles (Base Case) and 7.2 million used CANDU bundles (Alternate Case).
5.	The used fuel container (UFC) design will be optimised and a prototype container built prior to submission of the Canadian Nuclear Safety Commission (CNSC) licence and federal environmental assessment (EA) hearing for a preferred site.
6.	It is assumed that up to two candidate sites would be subject to detailed site characterisation and evaluation and as a result, two sites would be purchased or have options to purchase.
Construction	
7.	Detailed engineering design and Engineer, Procure and Construction (EPC) costs have been prepared by SNC-Lavalin (2011b).

8.	Detailed final engineering design and the preparation of working drawings for the facility will commence immediately following award of a site preparation and construction licence by the CNSC.
9.	The APM facility includes construction of a campsite. Any improvement or expansion of town site services or infrastructure is a contingent item subject to discussions between the NWMO and the community.
10.	The underground portion of the APM facility is assumed to be a network of horizontal tunnels and placement rooms for the UFCs excavated at a depth of 500 m in plutonic rock, with vertical shafts extending to surface. During construction of the underground facilities, unsuitable rock conditions are assumed for 10% of the in-floor borehole excavations in the placement rooms.
11.	The APM facility is designed to accommodate underground characterisation, technology demonstration and monitoring tests during operations and a period of extended monitoring until the site is ready for decommissioning.
12.	NWMO staff increases during construction are required for owner's acceptance of drawings, engineering packages, and general constructor oversight.
Operations	
13.	The APM facility operations will commence following the construction of the surface facilities, shafts, underground infrastructure and initial placement room panels and with the successful submission of the Final Safety Report and award of an Operating Licence by the CNSC.
14.	The design throughput of the APM facility will be 120,000 used fuel bundles per year resulting in 333 UFCs/year.
15.	All used fuel assumed to be transported to the APM facility via road. (Other modes of transport, such as mostly rail and mostly water, are possible).
16.	The APM facility will have all necessary staff and equipment to unload a transportation cask from the transport vehicle, conduct radiological surveys, unload used nuclear fuel from the cask and to prepare the empty cask for the return journey.
17.	The Used Fuel Packaging Plant (UFPP) is located at the APM facility site.
18.	All used fuel delivered to the APM facility will be received at the packaging plant in transportation casks and then packaged for placement underground.
19.	The UFC copper container and inner vessel will be fabricated at an unspecified off-site location(s) and then shipped 1,000 km to the APM facility. The cost of the copper container and inner vessel will include the cost of transporting the empty copper container and inner vessel to the site.
20.	NWMO's input to the cost estimate includes support required for licence renewals, monitoring, geoscience and social support during operations and long-term monitoring.
Extended Monitoring	
21.	The APM site infrastructure, surface buildings and underground works will be held in a care and maintenance regime for an extended period of monitoring following

	the completion of UFC placement operations. After this time, the site infrastructure and surface buildings will be made good for use during the decommissioning of the overall facility. By adopting this philosophy, all facilities will also be available should monitoring of the DGR identify the need to retrieve placed UFCs at any time during extended monitoring.
22.	During this preclosure period, the placement rooms will be sealed but the tunnels and shafts will remain open so that monitoring and access to the placement rooms is maintained.
Decommissioning and Closure	
23.	Decommissioning work is conducted by others.
24.	NWMO's staff support includes work required for licence renewals, monitoring, geoscience and social support.
25.	All major surface facilities are decontaminated, dismantled and removed. All underground tunnels, shafts and exploratory boreholes are backfilled and sealed.
26.	After major decommissioning activities are complete, institutional control, site security and monitoring of remaining infrastructure are maintained until a Site Abandonment licence has been obtained from CNSC.
Postclosure Monitoring	
27.	The specific requirements and activities associated with closure of the APM facility such as the nature and duration of postclosure monitoring are not known and will be decided in collaboration with a future society.
General	
28.	All labour, equipment and material costs are inclusive of any profit.
29.	The estimate is based on an APM facility design that receives CANDU used fuel bundles from the Canadian nuclear fuel waste owners (i.e., OPG, NBP, HQ and AECL).
30.	The scope of this estimate excludes consideration of non-standard nuclear fuels.
31.	All costs reflect the cost of local labour and materials.
32.	The cost estimate is prepared and budgeted in January 2010 current dollars and will be scheduled in elapsed time.

Therefore, the updated APM cost estimate has been developed using 2010 dollars. Unless otherwise stated, all cost estimates in this report are in 2010 dollars.

Year 01 costs are defined as APM costs incurred in 2010.

For financial planning purposes, Figure 2 illustrates the assumed schedule of the major APM activities through the phases of siting, design, construction, operation, decommissioning and closure.

		Illustrative APM Implementation Schedule	
Calendar Year	**Year**	**Major Activities and Assumptions for Financial Planning & Work Program**	
2007		Government Decision	
2008		**develop Siting Process**	
2009			
2010	Y01	Initial screening of communities Feasibility studies in potential sites Prelim field investigations	Initiate siting process; outreach activities Briefings & resources for communities Third-party reviews
2011	Y02		
2012	Y03		
2013	Y04		
2014	Y05	Surface & subsurface investigations in candidate sites Design & safety assessment work Select preferred site	Engage potentially affected communities Socio-economic impact assessments Detailed site investigations in collaboration with communities; discussion of benefits Negotiate terms & conditions for agreement
2015	Y06		
2016	Y07		
2017	Y08		
2018	Y09		
2019	Y10	Apply for Site Prep & Construction Licence Finalize site-specific design & safety assessment work for EA & licence	NWMO & community ratify formal agreement to host facility Benefits to host community
2020	Y11		
2021	Y12		
2022	Y13	Submit EIS & licensing documents Obtain Site Preparation & Underground Demo Facility Licence	Establish centre of expertise (surface), in partnership with community Participant support to EA process
2023	Y14		
2024	Y15		
2025	Y16	Construct Underground Demo Facility Begin site-specific demonstrations of repository technology Final design & safety assessment Obtain DGR Construction Licence	Establish centre of expertise (underground) Community offsets & benefits Socio-economic impact monitoring
2026	Y17		
2027	Y18		
2028	Y19		
2029	Y20		
2030	Y21	Apply for Operating Licence Construct initial components of DGR Obtain Operating Licence	Centre of expertise (surface / underground) Community offsets & benefits Socio-economic impact monitoring
2031	Y22		
2032	Y23		
2033	Y24		
2034	Y25		
2035	Y26	**begin APM DGR operation**	
…	…	…	…
…	…	…	…
2064	Y55	**end APM DGR operation**	
2065	Y56	**begin Extended Monitoring**	
…	…	…	…
…	…	…	…
2134	Y125	**end Extended Monitoring**	
2135	Y126	**begin Decommissioning & Closure**	
…	…	…	…
…	…	…	…
2159	Y150	**end Decommissioning & Closure**	
2160	Y151	**begin Postclosure Monitoring**	

Figure 2: Illustrative APM Implementation Schedule for 3.6 Million Bundle Scenario

5. WORK BREAKDOWN STRUCTURE

The Work Breakdown Structure (WBS) defines the APM project work elements for cost estimating purposes. Figure 3 shows the APM facility WBS work elements at Level 2.

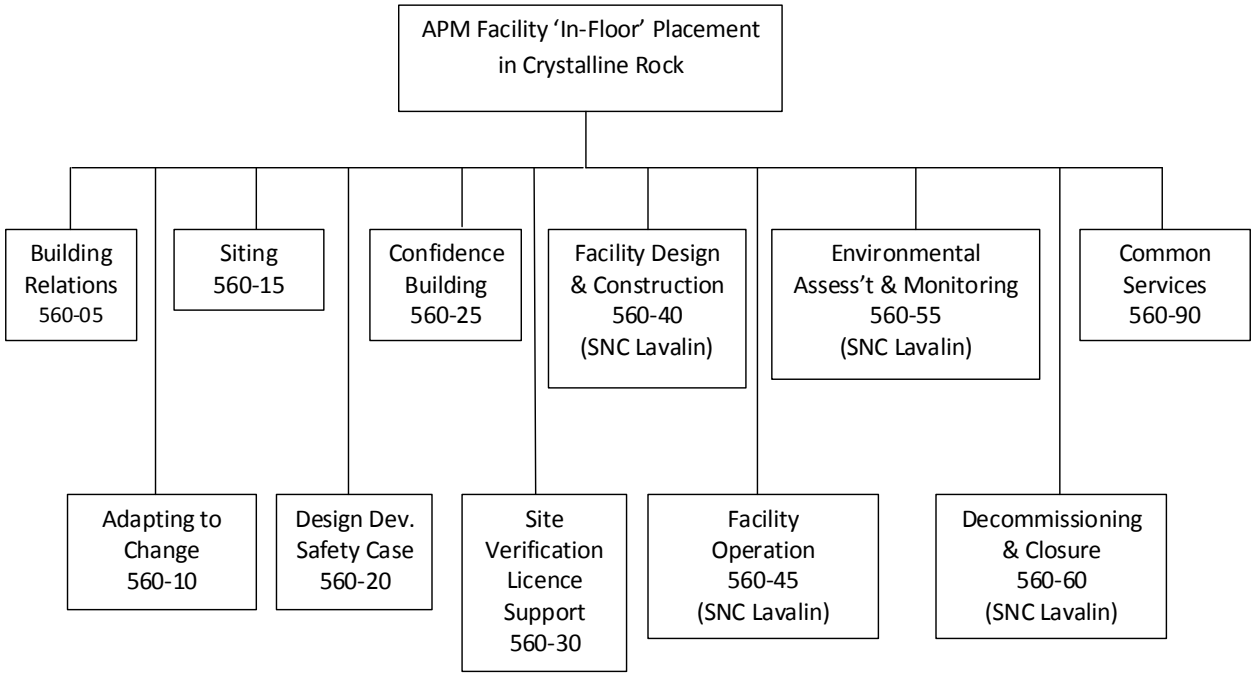

Figure 3: APM Work Breakdown Structure (WBS)

The WBS incorporates eleven Level 2 work elements that cover all the aspects of a program to site, design, develop, construct, operate, monitor, decommission and close an APM facility for used fuel.

The WBS also indicates the work element identifiers and the organisations (e.g., NWMO and SNC-Lavalin) that prepared the original estimates for the various areas of the project, on which the APM cost estimate has been based.

NWMO's input to the APM cost estimate addresses:

- 05 - Building Relationships
- 10 - Adapting to Change
- 15 - Siting
- 20 - Design Development & Safety Case
- 25 - Research & Confidence Building
- 30 - Site Verification & Licence Support
- 90 - Common Services

SNC-Lavalin's input to the APM cost estimate addresses:

- 40 – Facility Design & Construction
- 45 – Facility Operation
- 55 – Environmental Assessment & Monitoring
- 60 – Decommissioning & Closure

The following subsections describe the activities associated with the Level 2 work elements indicated in WBS.

5.1 560-05, BUILDING RELATIONSHIPS

Critical to the success of Adaptive Phased Management (APM) is the involvement of the Canadian public, including Aboriginal people, at all stages of implementation and in key decisions through open, transparent and inclusive engagement processes. In building relationships, the NWMO will seek and be responsive to a diversity of views and perspectives. NWMO will communicate and consult actively, promoting thoughtful reflection and facilitating a constructive dialogue in different aspects of APM implementation. A continuum of briefings, collaborative projects and partnerships will be advanced to support the further development and maintenance of relationships with municipal, Aboriginal and federal and provincial governments.

5.2 560-10, ADAPTING TO CHANGE

A fundamental tenet of APM is the ongoing incorporation of new learning and knowledge to guide decision making. NWMO has established a process for ongoing monitoring, review and reporting in areas of technological developments and societal views and expectations relating to APM implementation. NWMO reports regularly on its progress in implementing APM, especially in response to the advice of Canadians and the changing external environment.

5.3 560-15, SITING

The process to select an APM site in an informed and willing host community was initiated in May 2010. The siting process begins with a period of learning and capacity building for communities. The APM program assumes communities elect to progress through subsequent steps of screening, feasibility study and field investigations. The assumptions for this cost estimate are:

- Up to 2 sites enter detailed characterization and evaluation
- 1 preferred site selected

The end of the process is achieved with selection of one preferred site selected which is assumed to be completed in Year 09.

Although the activities related to siting are completed upon successful site selection, some financial obligations may continue beyond Year 09. These could include infrastructure commitments to the successful community and modelled commitments for a centre of excellence.

5.4 560-20, DESIGN DEVELOPMENT & SAFETY CASE

Design Development and Safety Case includes all activities related to the development of conceptual, feasibility and preliminary designs for the APM facility. The work activities include advancement of generic design concepts in support of site selection, site specific design advancement, unique technology advancement, generic and site specific safety cases. Specific activities focus on:

- Used fuel container development, demonstration and fabrication
- Site dependent repository designs
- Used fuel packaging plant conceptual design and demonstration
- Placement and retrieval systems
- Sealing materials
- Management support

Areas where technology requires additional development for deployment in the APM program are generally focused around the used fuel processes. Although a copper container has been produced by other national waste management organizations such as SKB (Sweden) and Posiva (Finland), their container dimensions are different from NWMO's current reference design for cost estimating. Application engineering would be required to customize and optimized the demonstrated products for NWMO's specific container type and size.

While the UFPP can reference a significant portion of established technology from SKB's more mature and demonstrated technologies with respect to container sealing, inspection and deployment underground, the Canadian CANDU fuel transfer operations for the UFPP require advancement of concepts in preparation of prototype units for technology demonstration.

Canada has demonstrated leadership in CANDU fuel transfer operations and this domestic expertise will be investigated for fuel transfer operations. Similar advancement programs are required for monitoring, container placement and retrieval, and sealing system demonstration.

5.5 560-25, CONFIDENCE BUILDING

A number of technical and scientific activities are being conducted to further increase confidence in the safety case for the APM facility and to improve NWMO's understanding of key scientific processes that may influence repository safety.

These confidence building and process understanding activities include models of the engineered barrier system, groundwater flow system evolution, integrated safety assessment models and full-scale demonstration of repository technology both in Canada and with international partners in joint research facilities.

5.6 560-30, SITE VERIFICATION & LICENCE SUPPORT

NWMO site verification and licensing activities support confirmation of site characteristics in support of licensing and environmental assessments. Also, site verification and licence support provide ongoing technical support required to obtain and maintain the various licences through construction, operation, long-term monitoring, decommissioning and closure of the APM facility. The functional areas contributing most significantly to site verification and licence support include repository safety, geoscience and regulatory affairs. Repository engineering also has some involvement in support of the licensing processes and monitoring technologies. Specific areas of work scope include:

- Establishing a geoscience information management system
- Site-specific geoscience activities to support:
    - Supporting the regulatory process by addressing regulatory questions
    - Monitoring at the preferred site
    - Numerical analysis during construction
    - DGR operation, extended monitoring, decommissioning and closure
- Repository Safety activities to support:
    - Update of safety case data sets
    - Preclosure and postclosure safety cases
    - ALARA, conventional, and radiological safety assessments
    - Natural analogues
    - Biosphere characterization and monitoring
    - Preparation of PSR and FSAR safety case reports
    - Human health monitoring included during extended monitoring
    - Operations, monitoring, decommissioning and closure safety assessments
    - Support the regulatory review
- Regulatory Affairs activities to support:
    - Preparation for EA, EA submission and public hearings
    - Government approvals at the federal, provincial and municipal level
    - Licence applications and hearings
    - Licence maintenance through all phases of the APM lifecycle
- Repository Engineering activities are in support of:
    - Ongoing monitoring activities
    - Safeguards

5.7 560-40, FACILITY DESIGN & CONSTRUCTION

The APM DGR Facility Design & Construction has been outlined in detail by SNC-Lavalin (2011b). The scope includes:

- Preferred Site Confirmation (excludes NWMO's scope of work)
- Site Improvements
- Construction Phase Indirects
- Surface Process Facilities
- Surface Auxiliary Facilities
- Underground Facilities

- Common Services (infrastructure structure for electrical distribution, communication, water system, sewerage, etc.)

5.8 560-45, FACILITY OPERATION (INCLUDING EXTENDED MONITORING)

The APM DGR Facility Operation has been outlined in detail by SNC-Lavalin (2011b). The scope includes operation and management functions for surface and underground facilities for the receipt of used fuel transported from the interim storage facilities to the UFPP at the APM facility, re-packaging the used fuel into long-lived UFCs and placement of the UFCs in the deep geological repository from Year 26 to Year 55 (Base Case).

APM facility operation and the UFPP have been designed to receive 120,000 used fuel bundles per year with an annual throughput of about 333 UFCs per year for placement in the repository. The Sealing Materials Compaction Plant will prepare the clay-based bentonite buffer rings and disks, backfill blocks and gap fill material for the underground placement rooms.

Following placement of the final UFC, operation of the APM facility will continue with a period of extended monitoring for up to 70 years from Year 56 to Year 125 (Base Case). The duration of extended monitoring will be decided in collaboration with a future society.

5.9 560.55, ENVIRONMENTAL MANAGEMENT & MONITORING

The APM DGR Environmental Management and Monitoring has been outlined in detail by SNC-Lavalin (2011b). The scope includes operation and management of the APM facility during extended monitoring following the final UFC placement underground.

5.10 560.60, FACILITY DECOMMISSIONING AND CLOSURE

The APM DGR Facility Decommissioning and Closure has been outlined in detail by SNC-Lavalin (2011b). The scope includes decommissioning management, construction and operation of related facilities and decommissioning and closure of the surface and underground. The nature and duration of postclosure monitoring will be decided in collaboration with a future society.

5.11 560-90, COMMON SERVICES

Common Services for the NWMO portion of the APM cost estimate describes the pre-operational program management costs from Year 01 to Year 25 and includes senior-level APM staff direction to the program, as well as project management and financial and business support for the program up to the point where operations commence.

Corporate quality assurance (QA) staffing for NWMO have been costed separately from Common Services and are carried in the NWMO estimate through Y01 to the end of the project at Year 151 (Base Case).

6. SUMMARY OF APM COST ESTIMATE

The current reference APM cost estimate for a deep geological repository in crystalline rock for the Base Case inventory of 3.6 million used CANDU fuel bundles is $17.9 billion (2010$), with a present value of $7.0 billion (2010$). The APM cost estimate includes allowances and contingencies which, on an aggregate basis, are 29% of the total estimate.

A summary of the APM cost estimate by implementation phase is given in Table 2.

Table 2: APM Cost Estimate by Implementation Phase

APM Phase	Year	Calendar	Cost 2010 $ ($ billion)
Siting	Y01 – Y15	2010 – 2024	$1.5
Construction	Y16 – Y25	2025 – 2034	$3.4
Operation	Y26 – Y55	2035 – 2064	$10.5
Extended Monitoring	Y56 – Y125	2065 – 2134	$1.5
Decommissioning & Closure	Y126 – Y155	2135 - 2164	$1.0
Total:			**$17.9**

The previous cost estimate for an APM deep geological repository and used fuel transportation system for 3.6 million used CANDU fuel bundles was $16.9 billion (2010$), with a present value of $6.9 billion (2010$).

A summary variance analysis for changes from the previous APM cost estimate prepared in 2003 and the current reference APM cost estimate prepared in 2011 is given in Table 3:

Table 3: APM Cost Estimate Variance Analysis

APM Cost Estimate (3.6 million used CANDU fuel bundles)	2010$ ($ billion)	2010$ PV ($ billion)
2003 estimate	**$16.9**	**$6.9**
Higher cost for “in-floor” placement of containers	$1.1	
Higher siting and engagement costs	$0.5	
Lower development costs after obtaining Construction Licence	$(0.3)	
Lower transportation costs (mostly labour)	$(0.3)	
Lower costs for facility decommissioning	$(0.2)	
Lower DGR operating labour rates	$(0.4)	
Other change	$0.1	
Additional contingency	$0.5	
2011 estimate	**$17.9**	**$7.0**

The increase in total lifecycle cost is due primarily to changes in mine design assumptions and placement method. The smaller increase in present value costs is due to an overall cost decrease in labour and associated reduction in escalated costs.

The annual cost and cumulative cost for the APM cost estimate for the Base Case inventory of 3.6 million used CANDU fuel bundles is illustrated in Figure 4.

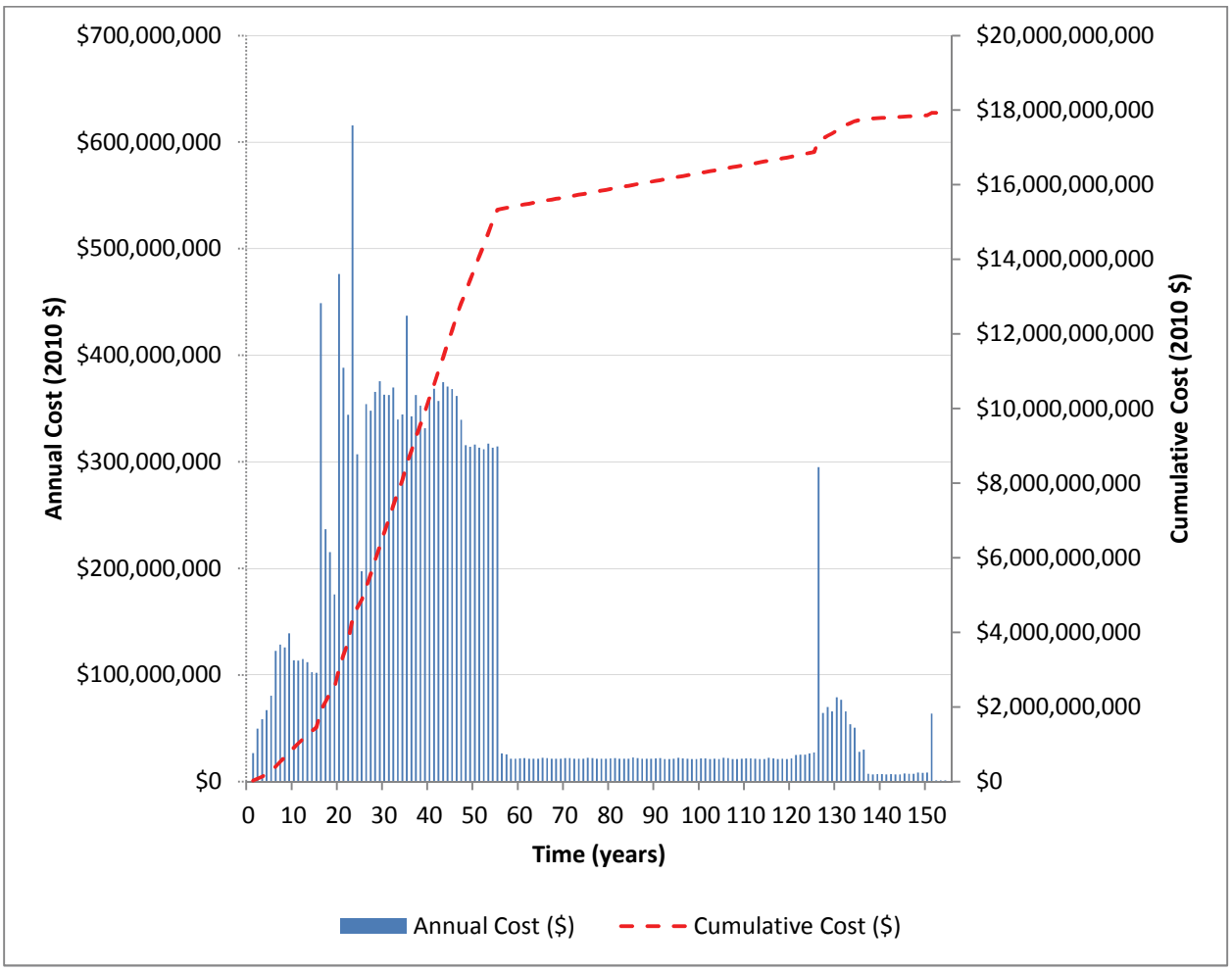

Figure 4: APM Annual and Cumulative Costs

The APM cost estimate for the Alternate Case inventory of 7.2 million used CANDU fuel bundles is $29.3 billion (2010$). To calculate the APM cost estimate for a used fuel inventory between 3.6 million and 7.2 million used CANDU fuel bundles, a straight line interpolation should be used.

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