nwmo

NUCLEAR WASTE MANAGEMENT ORGANIZATION

SOCIÉTÉ DE GESTION DES DÉCHETS NUCLÉAIRES

April 2005

NWMO BACKGROUND PAPERS
9. ASSESSMENTS

9-2b ASSESSMENT OF BENEFITS, RISKS AND COSTS OF A PROPOSED ADAPTIVE PHASED MANAGEMENT APPROACH BY ILLUSTRATIVE ECONOMIC REGION

SUPPLEMENTAL REPORT

Golder Associates Ltd., Gartner Lee Limited

NWMO Background Papers

NWMO has commissioned a series of background papers which present concepts and contextual information about the state of our knowledge on important topics related to the management of radioactive waste. The intent of these background papers is to provide input to defining possible approaches for the long-term management of used nuclear fuel and to contribute to an informed dialogue with the public and other stakeholders. The papers currently available are posted on NWMO's web site. Additional papers may be commissioned.

The topics of the background papers can be classified under the following broad headings:

1. **Guiding Concepts –** describe key concepts which can help guide an informed dialogue with the public and other stakeholders on the topic of radioactive waste management. They include perspectives on risk, security, the precautionary approach, adaptive management, traditional knowledge and sustainable development.
2. **Social and Ethical Dimensions** - provide perspectives on the social and ethical dimensions of radioactive waste management. They include background papers prepared for roundtable discussions.
3. **Health and Safety –** provide information on the status of relevant research, technologies, standards and procedures to reduce radiation and security risk associated with radioactive waste management.
4. **Science and Environment –** provide information on the current status of relevant research on ecosystem processes and environmental management issues. They include descriptions of the current efforts, as well as the status of research into our understanding of the biosphere and geosphere.
5. **Economic Factors** - provide insight into the economic factors and financial requirements for the long-term management of used nuclear fuel.
6. **Technical Methods** - provide general descriptions of the three methods for the long-term management of used nuclear fuel as defined in the NFWA, as well as other possible methods and related system requirements.
7. **Institutions and Governance** - outline the current relevant legal, administrative and institutional requirements that may be applicable to the long-term management of spent nuclear fuel in Canada, including legislation, regulations, guidelines, protocols, directives, policies and procedures of various jurisdictions.

Golder Associates

Gartner Lee

SUPPLEMENTAL REPORT ON

ASSESSMENT OF BENEFITS, RISKS AND COSTS OF A PROPOSED ADAPTIVE PHASED MANAGEMENT APPROACH BY ILLUSTRATIVE ECONOMIC REGION

Submitted to:

Nuclear Waste Management Organization

Prepared by:

Golder Associates Ltd. and Gartner Lee Limited

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1.0 INTRODUCTION

In 2002, the federal government passed the *Nuclear Fuel Waste Act* (NFWA)[1]. Among other things, the NFWA required the nuclear energy corporations within Canada (Hydro-Quebec, Ontario Power Generation Inc. and New Brunswick Power Corporation) to establish a new corporation, the Nuclear Waste Management Organization (NWMO). The purpose of the Act is to provide a framework to enable the government to make, from the proposals of the NWMO, a decision on the management of nuclear fuel waste that is based on a comprehensive, integrated and economically sound approach for Canada. The NWMO is to propose to the Government of Canada approaches for the management of nuclear fuel waste and implement the approach that is selected. The NFWA requires that the NWMO include, as a minimum, an analysis of three specific technical methods.

Each of the following methods must be the sole basis of at least one approach:

1. Deep Geological Disposal in the Canadian Shield;
2. Storage at Nuclear Reactor Sites; and
3. Centralized Storage, either above or below ground.

The NWMO has undertaken considerable background research, consultation and study since its inception, and has completed a preliminary assessment of these proposed approaches within a framework based on 10 key questions identified through extensive consultation with Canadians. The result of these activities, up to September 2004, are reported in two major discussion documents, "Asking the Right Questions"[2] and "Understanding the Choices"[3].

In November 2004, the NWMO retained Golder Associates Ltd (GAL) and Gartner Lee Limited (GLL) to carry out a comparative assessment of the benefits, risks and costs of implementing the above noted approaches in illustrative economic regions[4] of Canada. That assessment was prepared by GAL and GLL, supplemented with expertise from Nuclear Safety Solutions Limited and Econometric Research Ltd. It was undertaken using the eight guiding objectives which had been previously developed by the NWMO[5] in response to the 10 key questions identified in "Asking the Right Questions". The results of the assessment are presented in a Technical Report entitled "Assessment of Benefits, Risks and Costs of Management Approaches by Illustrative

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1 *An Act Respecting the Long-Term Management of Nuclear Fuel Waste*, assented to June 13, 2002.
2 Nuclear Waste Management Organization, *Asking the Right Questions? – The Future Management of Canada's Used Nuclear Fuel*, November 2003.
3 Nuclear Waste Management Organization,*Understanding the Choices – The Future Management of Canada's Used Nuclear Fuel*, September 2004.
4 Economic regions that have physical and socio-economic characteristics that are illustrative of many other economic regions across Canada.
5 Nuclear Waste Management Organization, *Understanding the Choices – The Future Management of Canada's Used Nuclear Fuel*, September 2004.

Economic Region" (GAL–GLL, 2005[6]). The results of that study concluded that all three approaches are technically feasible and could be implemented safely. However, each approach provided different benefits and posed different potential risks and costs in terms of the eight guiding objectives.

1.1 Fourth Management Approach –Adaptive Phased Management

Based on the input it has received, the NWMO has concluded that none of the management approaches specified in the NFWA perfectly addresses all of the objectives that Canadian citizens said were important for any management approach to address, particularly when both the near term and the longer term are considered. The NWMO's recommended approach, (termed "Adaptive Phased Management"), would be implemented in a step-wise manner and would require a decision by the appropriate authority at the end of each defined stage as to whether or not to proceed to the next stage, and whether or not the requirements of the next stage of implementation need to be adjusted based on knowledge gained, and on stakeholder review and participation. A staged approach would provide society with a number of opportunities to contribute to the decision making process and, in most cases, decisions could be revised and steps taken to retrieve the used nuclear fuel if desired or required.

To address the waste management issues identified by Canadians, the NWMO has developed a holistic, staged approach to long-term management of Canada's used nuclear fuel. Preliminary details of the Adaptive Phased Management Approach were developed by GAL-GLL through discussions and in conjunction with the NWMO prior to completion of an assessment of the benefits, risks and costs of implementing the Adaptive Phased Management Approach (see Section 1.2). The Adaptive Phased Management Approach comprises the following three high-level phases of implementation.

- Phase 1: Preparing for Central Used Fuel Management
- Phase 2: Central Storage and Technology Demonstration
- Phase 3: Long-term Containment, Isolation and Monitoring

The main features of each phase are described in Section 2 of this report.

1.2 Study Objectives

In February 2005, the NWMO retained GAL-GLL to carry out an assessment of the benefits, risks and costs of implementing the Adaptive Phased Management Approach, using the same methodology as was previously developed to assess the three approaches mandated by the NFWA

[6] Golder Associates Ltd. and Gartner Lee Limited, *Technical Report on Assessment of Benefits, Risks and Costs of Management Approaches for Used Nuclear Fuel by Illustrative Economic Region*, prepared for the Nuclear Waste Management Organization, February 2005.

(GAL-GLL, 2005). The objective of this additional assessment was to provide the NWMO with a comparison of the benefits, risks and costs of the Adaptive Phased Management Approach with those of the three mandated approaches (i.e., “Deep Geological Disposal in the Canadian Shield”, “Storage at Nuclear Reactor Sites”, and “Centralized Storage, either above or below ground”).

1.3 Steps in this Assessment

The assessment of the Adaptive Phased Management Approach was carried out using essentially the same methodology developed to assess the other three approaches described in the Technical Report (GAL-GLL, 2005). The assessment was conducted using the following four steps:

1. Review the measures and indicators previously developed for each of the influencing factors for each of the eight objectives and revise the measures and indicators if appropriate to the Adaptive Phased Management Approach.
2. Identify illustrative economic regions for implementation of the Adaptive Phased Management Approach that allow a comparison of the benefits, risks and costs of the approach with those of other approaches.
3. Conduct an analysis of the Adaptive Phased Management Approach across the applicable illustrative economic regions using information from the chosen measures and indicators.
4. Conduct a comparative assessment of the benefits, risks and costs of the Adaptive Phased Management Approach with those of the other approaches, taking into account the economic regions in which the approach would be implemented as well as ethical, social and economic considerations associated with the approach[7].

1.4 Organization of this Report

As this assessment is an extension of the previous Technical Report (GAL-GLL, 2005), this report has been prepared as a supplement. As such, this report concentrates primarily on the results of the assessment rather than the methodology or details of the assessment. The reader is referred to the previous Technical Report (GAL-GLL, 2005) for details regarding development and application of the study methodology, characteristics of the illustrative economic regions, and other background information.

Section 1 of this report introduces the fourth management approach, the Adaptive Phased Management Approach, and outlines the goal and objective of the assessment. Section 2 provides an overview of Adaptive Phased Management and describes how a cost estimate was developed for use in the benefits, risks and costs assessment. The illustrative economic regions used for assessing Adaptive Phased Management are identified in Section 3.

[7] *The Nuclear Fuel Waste Act*, Section 12 (4), 2002.

The analysis of Adaptive Phased Management with respect to each of the eight objectives is carried out in Section 4 through Section 11, in the following order:

- Public Health and Safety (Section 4);
- Worker Health and Safety (Section 5);
- Security (Section 6);
- Economic Viability (Section 7);
- Community Well-Being (Section 8);
- Environmental Integrity (Section 9);
- Adaptability (Section 10); and
- Fairness (Section 11).

Each of these sections (Sections 4 through 11) provides the results of the assessment of the Adaptive Phased Management Approach along with a comparison of all four management approaches.

Finally, Section 12 presents a summary comparing the advantages and disadvantages of the Adaptive Phased Management Approach relative to the other three approaches previously analyzed in the Technical Report (GAL-GLL, 2005).

2.0 ADAPTIVE PHASED MANAGEMENT APPROACH FOR USED NUCLEAR FUEL

2.1 The Adaptive Phased Management Concept

NWMO is recommending a fourth management approach that might better meet Canadian objectives than the other three approaches taken in isolation. It builds in sequential decision-making which would preserve flexibility during implementation. The three steps or phases of implementation are:

- **Phase 1: Preparing for Central Used Fuel Management**
- **Phase 2: Central Storage and Technology Demonstration**
- **Phase 3: Long-term Containment, Isolation and Monitoring**

The anticipated flow of used nuclear fuel through the life of the project is illustrated schematically on Figure 2-1 (see Appendix A).

At the present time (April 2005), the Adaptive Phased Management concept is in the early stages of development. Conceptual engineering design and cost estimates specific to the approach have not been completed. However, an extensive database of relevant conceptual design information and cost estimates exists as described in Table 2-1 (see Appendix A). Specifically, the Adaptive Phased Management concept is a compilation of desirable features from the previously developed Centralized Extended Storage-Casks in Rock Caverns (CES-CRC) concept[8] and the previously developed Deep Geological Repository (DGR) concept[9]. To allow a benefits, risks and costs analysis to be conducted, it can be assessed as such (see also Section 2.4).

[8] CTECH Radioactive Materials Management, *Conceptual Designs for Four Centralized Extended Storage Facility Alternatives for Used Nuclear Fuel*, April 2003.
[9] CTECH Radioactive Materials Management, *Conceptual Design of a Deep Geological Repository for Used Nuclear Fuel*, December 2002.

The Adaptive Phased Management Approach contains a number of key activities and decision points that preserve flexibility during implementation. While the NWMO does not know the precise duration of these activities or the outcome of future decisions, it can provide an indication of a representative schedule for implementation that can be used for preliminary planning and cost estimating purposes. As noted previously, the description of the approach is based on the conceptual design work and previous analyses of the other three management approaches that have been studied. Therefore, for illustrative purposes, a representative implementation of the Adaptive Phased Management Approach assumes that both the shallow below-ground storage (CES-CRC rock cavern facility at a nominal depth of 50 m) and a deep, long-term isolation facility (DGR facility at a nominal depth of 500 m to 1000 m) can be constructed at a common site in suitable geomedia such as the granite plutons which occur within Pre-cambrian rock of the Canadian Shield or in suitable sedimentary rock elsewhere in Canada, such as limestone or shale.

The Adaptive Phased Management Approach potentially includes three major facilities:

- A research laboratory and associated development program;
- A shallow, below-ground storage facility; and
- A deep isolation facility.

These major facilities are discussed briefly below.

A major research and development effort, including monitoring/participation in international programs and the construction and operation of a full-scale site-specific underground research laboratory will be undertaken in order to develop additional confidence in future decision-making. This effort was not anticipated in the conceptual designs for the previous three approaches. Cost allowances of $1.38 billion have been made in the current assessment to accommodate this research and development. This amount currently is believed to be sufficient for both participation in international research programs and the construction/operation of appropriate site and program specific research facilities on the selected Canadian long-term used nuclear fuel.

The shallow, below-ground storage facility is assumed to be essentially as described in CTECH 2003a (Table 2-1 –see Appendix A). Dry storage containers will be stored underground in rock caverns which are nominally 15 m wide by 16 m high by 452 m long. Each cavern will have a capacity of approximately 948 storage containers, and will include an access isle and an overhead gantry crane. The caverns will be constructed on a single level at a depth of nominally 50 m in either the Canadian Shield or other suitable rock and will be accessed via ramps sized to allow two-way traffic.

The deep, long-term isolation facility is assumed to be essentially as described in CTECH 2002 (Table 2-1 – see Appendix A). A separate, self-sufficient underground facility and new surface facilities for receiving, repackaging and emplacing the used nuclear fuel will be constructed. A complex of 104 placement rooms, each with the capacity to contain 108 used nuclear fuel containers (copper-clad long-term isolation containers), will be constructed at a nominal depth of 500 to 1,000 m. In all, the placement rooms together with access tunnels will take up an essentially square footprint of 2 km^2 in area (plan view). The complex will be served by four shafts and a variety of surface works.

2.2 Implementation Phases

As noted in Section 2.1, the Adaptive Phased Management Approach involves three major phases of implementation:

Phase 1: Preparing for Central Used Fuel Management

- Maintain storage and monitoring of used fuel at nuclear reactor sites;
- Develop with citizens an engagement program for activities such as design of the process of choosing a site, development of technology and key decisions during implementation;
- Select a central site that has rock formations suitable for shallow underground storage, an underground research laboratory and a deep geologic repository;
- Continue research into technology improvements for used fuel management;
- Undertake safety analyses and environmental assessment to obtain the required licences and approvals to construct the shallow underground storage, underground research laboratory and deep geologic repository at the central site, and to transport used fuel from the reactor sites;
- Construct the underground research laboratory at the central site;
- Decide whether or not to proceed with construction of shallow underground storage facility and to transport used fuel to the central site for storage during Phase 2; and
- If a decision is made to construct shallow underground storage, obtain an operating licence for the storage facility.

Phase 2: Central Storage and Technology Demonstration

- If a decision is made to construct shallow underground storage, begin transport of used fuel from the reactor sites to the central site for extended storage. If a decision is made not to construct shallow underground storage, continue storage of used fuel at reactor sites until the deep repository is available at the central site;
- Conduct research and testing at the underground research laboratory to demonstrate and confirm the suitability of the site and the deep repository technology;
- Engage citizens in the process of assessing the site, the technology and the timing for placement of used fuel in the deep repository;
- Decide when to construct the deep repository at the central site for long-term containment and isolation during Phase 3; and
- Complete the final design and safety analyses to obtain the required operating licence for the deep repository and associated surface handling facilities.

Phase 3: Long-term Containment, Isolation and Monitoring

- If used fuel is stored at a central shallow underground facility, retrieve and repackage used fuel into long-lived containers. If used fuel is stored at reactor sites, transport used fuel to the central facility for repackaging;
- Place the used fuel containers into the deep geologic repository for final containment and isolation;
- Continue monitoring and maintain access to the deep repository for an extended period of time to assess the performance of the repository system and to allow retrieval of used fuel, if required; and
- Engage citizens in on-going monitoring of the facility. A future generation will decide when to close the repository, decommission the facility and the nature of any post-closure monitoring of the system.

2.3 Implementation Schedule

For the purpose of this assessment, the assumed implementation schedule for the Adaptive Phased Management Approach is based on the following:

1. Previously developed schedules for implementing the CES-CRC concept (CTECH, 2003 a & b) and the DGR concept (CTECH, 2002 and 2003c).
2. An assumption that the earliest used nuclear fuel could begin to be placed into a long-term isolation facility is about year 60. This is based on a minimum allowance of about 30 years for site-specific, in-situ research and development (assumed to be years 20 to 50) and 10 years for design/licensing and construction of a DGR facility (CTECH, 2003c).

3. An assumption that the development workings (i.e., access shafts and tunnels) for the long-term isolation facility will remain open for a period of about 200 years to facilitate performance monitoring.

Based on these assumptions, the earliest time when decisions to proceed with implementing the approach can be made are as follows:

- Government adoption of Adaptive Phased Management Approach – year 1
- Decision to build shallow below-ground storage caverns at central site and transport used nuclear fuel to central site – approximately year 20
- Transport used nuclear fuel to central site – starting approximately year 30
- Decision to construct deep isolation facility – approximately year 50
- Place used nuclear fuel in a deep isolation facility – starting approximately year 60
- Decision to close shallow below-ground storage caverns – approximately year 110
- Decision to close deep isolation facility – approximately year 300

Figure 2-2 shows a high-level schematic of the representative implementation schedule for the Adaptive Phased Management Approach in comparison with the three previously considered management approaches. Figure 2-3 shows the relative duration of the project stages (GAL-GLL, 2005) for each of the four management approaches. It is important to note that the above timeframe could be modified depending on research findings and stakeholder input to future decision-making.

2.4 Implementation Costs

As noted in Section 2.1, conceptual engineering design studies and cost estimates for Adaptive Phased Management as an integrated approach to long-term used nuclear fuel management have not been completed. However, conceptual designs and cost estimates have been developed for each of the major components of the concept as indicated in Table 2-1 (see Appendix A). Consequently, to assess the economic viability of Adaptive Phased Management (Section 7), components of previously developed annual cash flow projections were compiled in accordance with the assumed implementation schedule (refer to Section 2.3) to derive a representative cash flow for the Adaptive Phased Management Approach. This cost estimation process required a number of working assumptions as discussed below.

<u>Phase 1: Preparing for Central Used Fuel Management</u>

As the intent is to eventually transfer used nuclear fuel from a shallow below-ground storage facility to a deep long-term isolation facility at the same central site, it is assumed that siting and initial development of the facility will be similar to developing a DGR (CTECH, 2003c, Table 2-1) and will require a period of 29 years from program initiation. During this period, used nuclear fuel will continue to be managed at the existing reactor sites using proven, safe storage technologies.

It is further assumed that during this first phase, transportation plans/options will be refined and developed and a major research and development program will be undertaken, including construction/operation of an underground research laboratory. This research and development program will start early in the project and continue through the commissioning of the deep long-term isolation facility.

In year 60, the underground research laboratory will become part of the deep long-term isolation facility and will be decommissioned and closed with it. Since the underground research laboratory (a distinct and separate facility from the underground characterisation facility assumed in DGR costs) was not anticipated by CTECH, an allowance, based on professional judgement and believed to be conservative, has been assigned to years 15 to 59 (inclusive) to capture potential costs associated with the total research and development effort. In all, $1.38 billion (in 2002 Canadian dollars) has been allowed for all aspects of this activity pending a conceptual design and formal cost estimate. This allowance includes design and construction costs of approximately $300 million and operations costs of approximately $30 million/year.

Phase 2: Central Storage and Technology Demonstration

It is assumed that during this second phase, dry storage containers are emplaced and stored in shallow below-ground caverns which are nominally 15 m wide by 16 m high by 452 m long, as in the CES-CRC concept previously developed by CTECH (CTECH, 2003a, Table 2-1 – see Appendix A). It is assumed used nuclear fuel will be emplaced in the shallow, below-ground storage facility from year 30 to year 59. It is expected that a portion of the used nuclear fuel would require repackaging upon receipt at the central facility and prior to initial placement.

The level of effort and costs for shallow below-ground storage are assumed to be those in CTECH's costs for CES-CRC (CTECH, 2003b), although allowing for a much shorter facility duration. For Adaptive Phased Management, the relevant data from CTECH are terminated at year 109. This may overestimate the costs for years 90 through 109 of Adaptive Phased Management, when the CES-CRC type facility is open, but presumed empty. Additionally, no repackaging costs during storage are included since it is assumed that the service life of dry storage containers is sufficient to safely contain fuel from the time of initial placement until transfer to the deep long-term isolation containers.

Phase 3: Long-term Containment, Isolation and Monitoring

It is assumed that beginning in year 60, used nuclear fuel will be transferred from the shallow below-ground storage facility (CES-CRC type facility) to a long-term isolation facility (DGR-type facility) located at the same central site. For costing purposes, it is assumed that a separate self-sufficient underground facility and new surface facilities for receiving, repackaging and re-emplacing the used nuclear fuel will all be constructed. Further, it is assumed that the long-term isolation operations will be analogous to those in the DGR concept previously developed by CTECH (CTECH, 2002, Table 2-1 – see Appendix A) and that relevant cost estimates are applicable, including annual cash flows developed by CTECH (CTECH, 2003c, Table 2-1 – see Appendix A).

To permit used nuclear fuel placement beginning in year 60, design and licensing of the deep long-term isolation facility will begin in year 30. Costs are assumed to be as developed by CTECH 2003c, with the following modifications: (1) start dates have been shifted to reflect the DGR type facility in-service in year 60, as opposed to year 30; and (2) the DGR-type facility will remain open for extended monitoring for a period of approximately 211 years (as opposed to 70 years in the CTECH concept). The former modification was merely the shift of the applicable series forward in time; the latter was accomplished by averaging annual costs from the original 70-year CTECH extended monitoring period and inserting 141 years of these average costs between years 129 and 130.

Used nuclear fuel will be transferred from the shallow below-ground storage facility to the deep long-term isolation facility over a 30 year period (year 60 to year 89). During this period, the shallow below-ground storage facility will remain in operation. By the end of year 89, it is assumed that all used nuclear fuel will be in place in the deep long-term isolation facility. It is assumed that the costs associated with fuel receipt in the CTECH estimates for a DGR-type facility are sufficient to allow for the retrieval of fuel from the CEC-CRC type facility and repackaging into used nuclear fuel containers.

The shallow below-ground storage facility is assumed to remain open for 20 years after the used nuclear fuel is transferred and to be closed in year 110. In year 110, the shallow below-ground storage facility will be closed by plugging the ramp and allowing the caverns to flood. Such closure costs were not anticipated by CTECH, and an allowance, based on professional judgement and believed to be conservative, has been assigned to years 106 to 114 (inclusive) to capture potential costs associated with the design, licensing, construction and monitoring of closure. In all, $20 million (in 2002 Canadian dollars) has been allowed for all aspects of this activity pending a conceptual design and formal cost estimate.

From years 90 to year 300, shafts and perimeter tunnels in the deep long-term isolation facility will remain open to allow extended monitoring of the sealed placement rooms containing the used nuclear fuel. Decommissioning and closure of the deep long-term isolation facility will begin in year 301 and conclude in year 325. Monitoring of the decommissioned and closed facility will continue from year 326 onwards in perpetuity.

Costs associated with decommissioning and closure are assumed to be those identified in CTECH 2003c (Table 2-1). These costs do not include a specific allowance for decommissioning and closure of the underground research laboratory.

As noted, post-closure monitoring and institutional control of the long-term isolation facility will commence in year 326 and will continue in perpetuity. An allowance on the order of $1 million per year would appear to be appropriate for post-closure monitoring. Accordingly, for present value cost estimates (see Section 7.3.5), a lump sum payment for post-closure monitoring of about $44.6 million in year 326 has been assumed, based on professional judgement, to allow for a discount rate of 5.75% and future (i.e., year 326 and beyond) annual inflation rates for labour, materials, other costs and contingency of 4%, 2%, 2.6% and 2.6%, respectively.

2.5 Geo-Environmental Conditions Conducive to Constructability and Predictability

In the previous benefits, risks and costs assessment (GAL-GLL, 2005), it was assumed that long-term isolation of used nuclear fuel involved construction of a Deep Geological Repository in the Canadian Shield (as required by the NFWA). For the current assessment, it is assumed that the Adaptive Phased Management facilities can be constructed either in suitable Pre-cambrian rock of the Canadian Shield such as a granite pluton or in suitable sedimentary rock such as shale, limestone or other suitable geomedia. Figure 2-4 shows a map of the Canadian Shield and selected Canadian Ordivician sedimentary formations which may contain rock suitable for an underground long-term isolation facility (see Appendix A).

3.0 ILLUSTRATIVE ECONOMIC REGIONS

3.1 Methodology for Selecting Illustrative Economic Regions

The previous assessment of benefits, risks and costs of alternative management approaches for used nuclear fuel in Canada (GAL-GLL, 2005) identified 11 illustrative economic regions (ERs) within which one or more of the management approaches could be implemented. Four of the illustrative ERs are located all or partially within the Canadian Shield and six represent the existing reactor site communities in Canada. The eleventh ER is not in the Canadian Shield and is not a reactor site community. The non-reactor site ERs were selected on the basis of four characteristics:

- Population;
- Environment;
- Transport distance; and
- Economics.

A summary of these four selection criteria is shown in Table 3-1.

TABLE 3-1:
SELECTION CRITERIA FOR ILLUSTRATIVE ECONOMIC REGIONS

Criterion	Measure	Canadian Range*	Illustrative Economic Region Range
Population	Density (Population/km^2)	~ 0.01 - 713	0.05 - 20
	Aboriginal Presence (% of population)	~0 - 90	1.2 - 83.4
Environmental	Terrestrial Ecozone- (Physiographic Classification – e.g., Boreal Shield, Mixedwood Plains)	15 types (including 3 Arctic)	7 types (including 2 Arctic)
	Drainage Region	Five Regions	Three Regions
Transport Distance (for majority of used nuclear fuel)	Distance (km)	~ 0 - 6,000	~ 300 - ~ 3,500
Economics	Economic Base/Major Industrial Groups (e.g., Manufacturing, Agriculture)	20	7
	% Agricultural Land	~ 0 - 48%	~ 0 - 48%
	Average Household Income ($/year)	$31k - $65k	$31k - $50k

Note:
* Represents the range of each criterion within Canada's 76 ERs

To facilitate a comparison of the benefits, risks and costs of the Adaptive Phased Management Approach with those of the other three management approaches, the current assessment is based on a sub-set of the previously identified illustrative ERs. This sub-set was selected using the selection criteria in Table 3-1 and the technical requirements of Adaptive Phased Management: specifically, that the interim storage caverns and long-term isolation facilities could be located in suitable Pre-cambrian rock of the Canadian Shield such as a granite pluton or in suitable sedimentary rock or other suitable geomedia (see Section 2.5).

3.2 Identification of Illustrative Economic Regions

Based on the selection criteria and technical requirements of the approach, four illustrative ERs were identified for the assessment of Adaptive Phased Management:

ER-2: located in the Canadian Shield and representing a long transportation distance for the used nuclear fuel.

ER-4: located partially in the Canadian Shield and partially within the Hudson Bay Sedimentary Basin, an area of potentially suitable sedimentary rock (see Figure 2-5, Appendix A).

ER-5: an existing reactor community in Southern Ontario underlain by potentially suitable sedimentary rock.

ER-9: located in the Canadian Shield and previously identified as an illustrative ER for implementation of both Centralized Extended Storage and Deep Geological Disposal approaches, also identified as representing a long transportation distance for the used nuclear fuel.

It is important to note that using these four illustrative ERs is not an attempt to indicate or preclude a preference for siting. Rather, these four ERs simply illustrate the range of possible impacts and issues attendant with the Adaptive Phased Management Approach.

The characteristics of these four illustrative ERs are shown in Table 3-2.

TABLE 3-2:
ILLUSTRATIVE ECONOMIC REGIONS WITH SELECTION CRITERIA

Criteria and Measure	Saskatchewan ER-2	Ontario ER-4	Ontario ER-5	Quebec ER-9
Population: Density (Persons/km^2)	0.1 Low	2 Low	20 Medium	0.05 Low
Population: Aboriginal Presence (% of Population)	83.4 High	7.7 High	1.2 Low	54.9 High
Environmental: Terrestrial Ecozone	• Boreal Plains • Boreal Shield • Taiga Shield	• Boreal Plains • Hudson Plains	• Mixedwood Plains	• Boreal Shield • Hudson Plains • Taiga Shield • Southern Arctic • Northern Arctic
Environmental: Drainage Region	• Arctic Ocean • Hudson Bay	• Hudson Bay • Atlantic Ocean	• Atlantic Ocean	• Atlantic Ocean
Transport distance (for majority of used nuclear fuel, where applicable)	~ 3,500 km Long	~1,000 km Medium	~ 300 km Short	~ 2,000 Long
Aboriginal Presence (% of Population)	83.4 High	7.7 Medium	1.2 Low	54.9 High
Economic: Top four Industries	• Government • Education Services • Health Care • Retail	• Retail • Health Care • Manufacturing • Hospitality	• Manufacturing • Retail • Agriculture, Forestry & Fishing • Health Care	• Health Care • Government • Educational Services • Manufacturing
Economics: % Agricultural Land	0.9	0.5	47.9	0
Economics: Household Income ($/yr.)	31,106	41,992	46,278	50,187

Range: Population Density (High - >20; Medium: 2 – 20; Low - <=2);
Transport Distance (Long - > 2000 km; Medium – 500 – 2,000 km; Short - <= 500 km);
Aboriginal Presence (High - >20%; Medium – 5-20%; Low - <=5%)

In summary, the four identified illustrative ERs used for the assessment of Adaptive Phased Management include the following characteristics:

- Long, medium and short transportation distance;
- Medium and low population density;
- High, medium and low aboriginal presence;
- A range of leading industries – government, educational service, health care, retail, manufacturing and hospitality – and a range of agricultural activity; and
- Three provinces including those with and without nuclear power generation.

4.0 ANALYSIS OF PUBLIC HEALTH AND SAFETY

4.1 Context for the Analysis of Public Health and Safety

***Objective**: Public health ought not to be threatened due to the risk that people might be exposed to radioactive or other hazardous materials. Similarly, the public should be safe from the threat of injuries or deaths due to accidents during the transportation of used nuclear fuel or other operations associated with the approach*[10].

4.2 Influencing Factors and Measures Used in the Analysis of Public Health and Safety

Similar to the analysis of the other approaches (GAL-GLL, 2005), the following influencing factors and measures are used in the assessment of the Adaptive Phased Management Approach:

Influencing Factors used in Preliminary Comparative Assessment	**Influencing Factors used in this Analysis**	**Measures Used in this Analysis**
Size of population potentially at risk	Size of public population at risk • Public adjacent to facility • Public adjacent to transportation route	• Number of public at risk
Seriousness of potential consequences to impacted individuals • Normal operations (radiological, vehicle accident) • Off-normal scenarios (unintended intruder, facility accident, unanticipated vehicle accident, unanticipated deterioration of barriers) • Effectiveness of safety barriers and institutions	Seriousness of potential consequences to the public • Normal operations (radiological, transportation) • Off-normal conditions (human intrusion, climate change, facility failure, accident in transport) • Loss of institutional control	Radiological risks • Dose to the public Transportation Accidents (Conventional) • Fatalities • Injuries
Duration of potential health consequences (short, temporary or long-term)	• Duration of health impact	• Time of peak impact
Ability to respond to, correct, remove, mitigate		

[10] The Nuclear Waste Management Organization, *Understanding the Choices – The Future Management of Canada's Used Nuclear Fuel*, September 2004, pg. 58.

Influencing Factors used in Preliminary Comparative Assessment	Influencing Factors used in this Analysis	Measures Used in this Analysis
Likelihood of impacted individuals experiencing consequences • Likelihood to typical, average individual • Likelihood of impact to most sensitive individual • Likelihood of impact to the individual at maximum risk	Likelihood of member of public experiencing consequences • Maximum exposure • Maximum impact	• Probability of maximum impact to receptor

4.3 Results of Public Health and Safety Analysis

The methods and details used in the following analyses are generally similar to those used in the assessment of the other approaches, as described in the Technical Report (GAL-GLL, 2005). However, this analysis assessed the public health and safety of Adaptive Phased Management across the three phases of the project (refer to Section 2).

4.3.1 Number of Public at Risk

The number of people potentially at risk relates to the size of the population potentially at risk, including the public adjacent to the facility and adjacent to the transportation routes. For the purposes of this analysis, it was assumed that the number of public adjacent to the facility is proportional to the population density of the ER where the facility is located[11]. Table 4.3-1 summarizes the population densities of the ERs considered for the Adaptive Phased Management Approach. Those ERs with a higher population density will likely have more members of the public at the facility fence line than those with a low population density.

TABLE 4.3-1: ILLUSTRATIVE ECONOMIC REGIONS AND ASSOCIATED POPULATION AND TRANSPORTATION CRITERIA

Illustrative Economic Region	Population Density (person/km^2)	Approximate Transport Distance (km)
ER-2	0.1 (Low)	~3,500 (Long)
ER-4	2 (Low)	~1,000 (Medium)
ER-5	20 (Medium)	~260 (Short)
ER-9	0.05 (Low)	~2,000 (Long)

[11] The cost estimate for the implementation of the Adaptive Phased Management Approach assumes that it occurs on a “greeenfield” site, so the population density at the perimeter fence would likely be proportional to a newly established settlement, not to the overall ER density. However, for comparative purposes at this time, population densities of the illustrative ERs are known and were used as noted above.

Members of the public along the transportation route may also have a measurable risk during the approximate 30 year transportation activities. Table 4.3-1 also shows the approximate transport distance to the destination ERs. Those ERs with a longer transportation route will potentially expose more members of the public than those with shorter transportation routes depending upon the number and size of population centres along the routes and the transportation methodology chosen.

For each of the bounding exposure scenarios considered for the radiological assessment (see Section 4.3.2) hypothetical public receptors were identified. Table 4.3-2 summarizes the characteristics and estimated number of public affected in each scenario. Information in this table shows that only a small number of people are at risk and those most affected are likely to be in close proximity to the facility.

TABLE 4.3-2:
NUMBER OF MEMBERS OF THE PUBLIC POTENTIALLY AT RISK FOR THE ADAPTIVE PHASED MANAGEMENT APPROACH[12]

Phase of the Adaptive Phased Management Approach	Bounding Exposure Scenario	Estimated Number of People at Risk
Normal Conditions		
Phase 1: Interim Storage at Reactor Sites	External exposure at fence boundary	Small number of people at facility fence
Phase 2: Extended Storage at Central Facility	Routine airborne and water emissions	Small number of people at facility fence (likely smaller number than Phase 1 as there is only one site)
Phase 3: Operations	Routine airborne and water emissions	Small number of people at facility fence (likely smaller number than Phase 1 as there is only one site)
Phase 3: Postclosure	Groundwater pathway	Self-sufficient local farmers
Off-Normal Conditions		
Phase 1: Interim Storage at Reactor Sites	Dropping of a loaded DSC in the process building	Small number of people at facility fence
Phase 2: Extended Storage at Central Facility	Dropping of a loaded DSC in the process building	Small number of people at facility fence (likely smaller number than Phase 1 as there is only one site)
Phase 3: Operations	Failure in the shaft and hoisting facilities, along with ventilation failure	Small number of people at facility fence (likely smaller number than Phase 1 as there is only one site)
Human Intrusion Scenarios		
Phase 2: Extended Storage at Central Facility	Human Intrusion	Indeterminate. Depends on the intrusion scenario.
Phase 3: Postclosure	Human Intrusion	Indeterminate. Depends on the intrusion scenario; likely very few.

[12] NSS Limited, *Used Nuclear Fuel Management Options, Radiological Safety Review of Staged Management Approach*. GA001. Internal Draft. February 10, 2005.

4.3.2 Risks Due to Exposure to Radiation

For Adaptive Phased Management, the radiological impact to members of the public under normal and off-normal conditions was determined and compared against the Canadian limit[13,14]. Bounding case impacts were calculated for each phase of the approach; these are summarized in Table 4.3-3. These bounding cases and data sources are discussed below.

Phase 1: Preparing for Central Used Fuel Management

Phase 1 is the continuation of existing storage of used nuclear fuel at the reactor sites using proven technology. The public safety assessment of the Storage at Nuclear Reactor Sites approach is considered applicable to this phase. This is likely a conservative assumption as there will be no repackaging of the used nuclear fuel during this phase.

Phase 2: Central Storage and Technology Demonstration

During Phase 2, used nuclear fuel from existing reactor sites will be repackaged as necessary, into self-shielded dry storage containers and stored in a single, central facility at approximately 50 m below grade, constructed in a suitable rock formation.

With respect to the initial handling of used nuclear fuel (receiving and repackaging), radiological impact from Phase 2 of the Adaptive Phased Management Approach are expected be no greater than to those of the Centralized Storage (below ground) approach. The bounding normal and off-normal scenarios for this phase were assumed to be similar to those for the Centralized Storage (below ground) approach (i.e., dropping of a fuel assembly and fuel cask).

Phase 3: Long-Term Containment, Isolation and Monitoring

During Phase 3, the dry storage containers will be transferred to surface, repackaged into long-lived disposal containers, returned underground and emplaced within the long-term isolation facility. This phase is similar to Deep Geological Disposal in the Canadian Shield. Additional safeguards will be provided through enhanced monitoring and appropriate institutional controls.

The bounding scenarios for Phase 3 were assumed to be similar to those for Deep Geological Disposal in the Canadian Shield. However, because of radioactive decay during the storage period of Phase 2, the dose to the public is likely to be lower than the estimated doses for Deep Geological Disposal in the Canadian Shield.

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[13] Canada Gazette, *Nuclear Safety and Control Act and Regulations*, Part II, Vol. 134, June 13, 2000; and International Commission on Radiological Protection (ICRP), *Recommendations of International Commission on Radiological Protection*, ICRP Publication 60, Ann. ICRP, Vol. 21, 1991, pp. 1-3, 1991.
[14] Canadian Nuclear Safety Commission, *Safety Analysis of CANDU Nuclear Power Plants*, C-006 Rev. 1, 1999.

Summary of Radiation Exposure Risks

During normal conditions, all radiation doses predicted for all phases are well below the regulatory criteria. Additionally, with the exception of some human intrusion scenarios during Phase 2 and early in Phase 3, all off-normal radiation doses are expected to be well below the applicable criteria.

During Phase 1 and 2, with the appropriate institutional control in place, the likelihood of inadvertent human intrusion into the storage facilities is very low since the facility will be a secure and located entirely within the fenced and access-controlled site. Correspondingly, resulting radiation exposure to members of the public is negligible; however, with a loss of institutional control, human intrusion before decommissioning and closure of the isolation facility is possible. Inadvertent human intrusion may result in doses greater than 1 mSv/y; however, the site selection and design of the below-ground storage facility can ensure that the probability of intrusion is minimized.

During Phase 3, following closure there is a very low probability of human intrusion into the long-term isolation facility, regardless of whether or not institutional controls are maintained.

TABLE 4.3-3: RADIATION RISKS FROM BOUNDING CASES FOR ADAPTIVE PHASED MANAGEMENT

Adaptive Phased Management Phase	Bounding Case	Max Dose (mSv/y)	Probability	Estimated number of People Affected	Time of Peak Impact	Limit (mSv/y)	% of the Limit
Normal Conditions							
Phase 1	External exposure at fence boundary	0.0003	1	Small number of people at boundary of facilities	During storage at reactor site	1	0.03
Phase 2	External exposure at fence boundary	0.0003	1	Smaller number of people than in Phase 1 as there is only one facility	During placement of used nuclear fuel in storage in extended storage facility	1	0.03
Phase 3 (before closure of isolation facility)	Routine airborne and waterborne emissions	Adult: <0.00034 Infant: <0.00052	1	Persons living at facility boundary (smaller than in Phase 1, equivalent to Phase 2)	During placement of used nuclear fuel into isolation facility	1	<0.034 <0.052
Phase 3 (postclosure)	Groundwater pathway	$< 10^{-4}$	1	Self-sufficient farmer in local area	500,000 years postclosure	1	<0.01
Off-normal Conditions							
Phase 1	Dropping of a loaded DSC in the process building	0.005	$<10^{-7}$	Small number of people at facility fence	Placement of used nuclear fuel in storage	250	0.002
Phase 2	Dropping of a fuel assembly and fuel cask	0.00002	Not known	Smaller number of people than in Phase 1 as there is only one facility	Placement of used nuclear fuel into extended storage facility	1	0.002
Phase 3 (before closure)	Failure of the shaft and hoisting facilities, along with ventilation failure	Adult: <0.16 Infant: <0.25	$3x10^{-4}$	Persons living at facility boundary (smaller than in Phase 1, equivalent to Phase 2)	Placement of used nuclear fuel into isolation facility	100	<0.16 <0.25
Human Intrusion Scenarios							
Before Closure	Loss of institutional control resulting in human intrusion into facility	>1000 mSv	Probable before year 325	Depends on the intrusion scenario	At the time of intrusion	-	-
Postclosure	Loss of institutional control in intrusion by drilling and retrieval of the core	<200 mSv	$6x10^{-9}$	Depends on the intrusion scenario	At the time of intrusion	-	-

4.3.3 Risks from Transportation

Off-site transportation is required in Phase 2 of the Adaptive Phased Management Approach, as the used nuclear fuel is transported from the existing reactor sites to the new central site. The analysis of radiological risks from transportation presented in the Technical Report (GAL-GLL, 2005) is applicable to Adaptive Phased Management. In summary, all the predicted doses are within the Canadian dose limit of 1 mSv/y for normal scenarios. For off-normal scenarios, if the radiation dose limit applied to the nuclear generating station is applied to transportation accidents, the worst case transportation accident with an annual frequency of less than 1×10^{-5} is bounded by a constraint of 250 mSv/y[15]. The analysis showed that the maximum dose ranges from 9 to 40 mSv/y, which is well within the acceptable limit.

Conventional risks of transportation were estimated using casualty rates and the total truck kilometres (rounded up to the nearest significant digit) anticipated for each of the illustrative, destination ERs considered for Adaptive Phased Management. The number of truck kilometres includes both the trip to the management facility and the return trip. Table 4.3-4 summarizes the potential injury and fatality rates for each of the ERs.

TABLE 4.3-4:
SUMMARY OF ESTIMATED CASUALTY RATES DUE TO TRANSPORTATION FOR THE ADAPTIVE PHASED MANAGEMENT APPROACH BY DESTINATION ECONOMIC REGIONS

Destination Illustrative Economic Region	Total Truck Travel (billion km)	Total Estimated Fatalities[a]	Total Estimated Injuries[b]
ER-2	0.14	1.2	100
ER-4	0.04	0.4	28
ER-5	0.01	0.1	7
ER-9	0.08	0.8	56

[a] Based on Canadian average rate of 8.9 fatalities per billion vehicle-kilometres
[b] Based on Canadian average rate of 711 injuries per billion vehicle-kilometres

4.4 Summary of Public Health and Safety Analysis

Public health and safety relates to the likelihood that members of the public proximate to the facility or along the transportation route might be exposed to unacceptable radiological and conventional risks as a result of implementing the approach. The management approach, the construction methods and the operational and monitoring procedures should be such that, in addition to complying with good engineering practices and all industrial safety regulations, the public will not be subject to risks or harmful exposures, chronic or accidental, greater than those acceptable to Canadian and international authorities at the present time. However, acceptable

[15] Canadian Nuclear Safety Commission, *Safety Analysis of CANDU Nuclear Power Plants*, C-006 Rev. 1, 1999.

levels or standards may change with time and current measures of risk might therefore change. Security and terrorism as a threat to public health and safety is discussed in Section 6.

The assessment used quantitative information available in the literature or capable of being estimated within the timeframe available for the assessment and builds on the approach used by the NWMO Assessment Team (refer to GAL-GLL, 2005) and GAL/GLL in similar studies. Information was developed for Adaptive Phased Management within each of the four illustrative ERs as appropriate. This included the identification of the radiological and physical risks associated with each approach, including transportation of the used nuclear fuel.

A summary of public health and safety analysis for Adaptive Phased Management in terms of their benefits, risks and costs is discussed below. Following that, a rollup comparison of all four management approaches is presented in Table 4.4-1.

Benefits

The Adaptive Phased Management Approach can be built and operated to meet applicable safety criteria with a considerable margin of safety under normal conditions. Also, under off-normal conditions, radiation exposure is well below the applicable criteria for the near and long-term, with the exception of some human intrusion scenarios. During the long-term, with or without institution controls, the risk to the public from off-normal conditions is very low once the deep isolation facility is decommissioned and closed.

Risks

The risks to public health and safety from the Adaptive Phased Management Approach are low. However, this approach involves real and perceived risks, including risks associated with transporting used nuclear fuel.

During normal and off-normal conditions in the near term, potential radiation exposures would occur during or just after placement of the used nuclear fuel in the shallow below-ground facility or in the deep isolation facility.

For Adaptive Phased Management, the probability of human intrusion in the long-term (post closure) is extremely low.

If there is a loss of institutional control before decommissioning and closure (i.e., year 325 for Adaptive Phased Management), there is no assurance of preventing an unacceptable radiation risk to public health caused by an inadvertent human intrusion. In the long-term, for some off-normal scenarios, there is a perceived risk to the public from the escape of some radioactivity via the groundwater pathway at some unspecified point in the future. As described in the section on Environmental Integrity (see Section 9) studies have found that the predicted impact of any groundwater release from these facilities are well below the applicable standards, although some uncertainty may remain because of the long time periods.

Transportation activities can be designed and carried out safely and meet all applicable criteria. Risks from off-normal transportation conditions increase with the transportation distance.

Costs

Costs of radiation protection and public safety are accounted for in the economic costs of the Adaptive Phased Management Approach through facility designs and monitoring programs using today's technology and standards.

TABLE 4.4-1: SUMMARY OF PUBLIC HEALTH AND SAFETY ANALYSIS – A COMPARISON OF MANAGEMENT APPROACHES: BENEFITS, RISKS AND COSTS

Measure or Indicator	Benefits	Risks	Costs
Number of People at Risk	• Deep Geological Disposal in the Canadian Shield and the Adaptive Phased Management approaches have potentially less people at risk since these approaches may be located in ERs with lower population densities than Storage at Nuclear Reactor Sites, assuming current population distributions continue.	• Regardless of the approach, there are more members of the public exposed in ERs with higher population densities than in those with low population densities. • Storage at Nuclear Reactor Sites will have a larger number of people at risk than Centralized Storage (above or below ground), Deep Geological Disposal in the Canadian Shield and the Adaptive Phased Management approaches in the near and long term because the used nuclear fuel is stored at seven separate sites. • Deep Geological Disposal in the Canadian Shield, Centralized Storage (above or below ground) and the Adaptive Phased Management approaches have people at risk along the transportation route. • Economic regions farther away from the source of the used nuclear fuel will potentially expose more members of the public to risk.	• There are no costs associated with this measure.
Radiological Dose to the Public	• Under normal operations all approaches are capable of meeting applicable criteria in the near and long-term. • Radiation exposures for normal and off-normal transportation activities are statistically insignificant. • After closure, Deep Geological Disposal in the Canadian Shield and the Adaptive Phased Management approaches offer protection from unacceptable risks through unauthorized or inadvertent intrusion into the wastes in the long-term.	• Following a loss of institutional control in the long-term, Storage at Nuclear Sites and Centralized Storage (above or below ground) do no prevent an unacceptable radiation exposure risk to public health and safety caused by an intrusion. The resulting unacceptable exposure will persist for hundreds of thousands of years. • Between Year 154 and 325 (i.e., prior to closure), if there is a loss of institutional control, Adaptive Phased Management does not prevent a unacceptable radiation exposure risk to public health and safety caused by human intrusion. • There are no differences between ERs.	• Costs of radiation protection are accounted for in the economic costs of all approaches through facility designs and monitoring programs using today's technology and standards. • There are no differences between ERs.
Estimated Fatalities and Injuries Due to Transportation	• There are no conventional transportation risks associated with Storage at Nuclear Reactor Sites as there is no off-site transportation associated with this approach.	• Deep Geological Disposal in the Canadian Shield, Centralized Storage (above and below ground) and the Adaptive Phased Management approaches have off-site transportation and associated transportation risks. • The estimated number of injuries is small for all ERs and is proportional to transport distance. • More than one potential fatality is only predicted for the longest transportation route.	• The costs associated with transportation are included in the economic costs of the approaches.

Measure or Indicator	Benefits	Risks	Costs
Time of Peak Impact	• For Storage at Nuclear Reactor Sites and Centralized Storage (above or below ground), movement of radioactivity is prevented through active management and institutional controls.	• During normal and off-normal conditions in the near term, potential exposures are expected during or just after placement of the fuel in the facility. • For Deep Geological Disposal in the Canadian Shield and the Adaptive Phased Management approaches, movement of radioactivity through the groundwater pathway is possible for hundreds of thousands of years into the future (although predicted impact is well below applicable standards because of isolation provided by the host geological formation). • Repackaging cycles associated with Storage at Nuclear Reactor Sites and Centralized Storage (above or below ground) cause an associated radiation exposure well into the future (greater than 10,000 years). • Human intrusion into Centralized Storage (above or below ground) and Storage at Nuclear Reactor Sites may result in an unacceptable risk to the public in the near term and long term if institutional control cannot be maintained. • If institutional control is not maintained through year 325 (i.e., before closure), human intrusion into the Adaptive Phased Management facility is likely with the resulting unacceptable radiation exposures. • Time of peak impact is independent of ER.	• Costs of radiation protection are accounted for in the economic costs of the management approaches.
Probability of Maximum Impact to Receptor	• There are no benefits associated with this measure.	• The probability of the bounding off-normal scenarios during the near-term for all approaches is very low (less than 10^{-4}). • The probability of human intrusion into the Deep Geological Disposal in the Canadian Shield in the long-term and the Adaptive Phased Management approaches after decommissioning and closure (Year 325) is very low (less than 10^{-7}). • If institutional control is not maintained in the near term and long term, human intrusion into the management facility for Storage at Nuclear Reactor Sites and Centralized Storage (above or below ground) is likely with the resulting unacceptable radiation exposures. • If institutional control is not maintained through year 325 (i.e., before closure), human intrusion into the Adaptive Phased Management facility is likely with the resulting unacceptable radiation exposures.	• There are no costs associated with this measure.

5.0 ANALYSIS OF WORKER HEALTH AND SAFETY

5.1 Context for the Analysis of Worker Health and Safety

Objective: *Construction, mining, and other tasks associated with managing used nuclear fuel can be hazardous. It is desirable that the selected approach not create undue or large risks to the workers who will be employed to implement it*[16]*.*

5.2 Influencing Factors and Measures Used in the Analysis of Worker Health and Safety

Similar to the analysis of the other three approaches described in the Technical Report (GAL-GLL, 2005), the following influencing factors and measures are used in the assessment of the Adaptive Phased Management Approach:

Influencing Factors used in Preliminary Comparative Assessment	Influencing Factors used in this Analysis	Measures Used in this Analysis
Size of population potentially at risk	Size of workforce at risk	• Number of workers during each stage
Seriousness of potential consequences to impacted individuals • Normal operations (radiological, conventional and industrial hazards) • Off-normal scenarios (radiological, construction accidents, extreme handling accidents) Duration of potential health consequences (short, temporary or long-term) Ability to respond to, correct, remove, mitigate	Seriousness of potential consequences to workers • Normal operations (radiological, conventional and industrial hazards) • Off-normal scenarios (radiological, construction accidents, extreme handling accidents) Duration of health consequences	Radiological risks • Dose to workers Conventional occupational risks • Risk of injury or fatality Stage during which consequence may occur
Likelihood of impacted individuals experiencing consequences	Accident statistics in representative industrial sectors	• Lost Time accident Frequency Rate (LTAFR) • Total Recordable Accident Frequency Rate (TRAFR)

[16] Nuclear Waste Management Organization, *Understanding the Choices – The Future Management of Canada's Used Nuclear Fuel*, September 2004, pg 60.

5.3 Results of Worker Health and Safety Analysis

The methods and details used to assess worker health and safety are similar to those used in the assessment of the other three approaches, as described in the Technical Report (GAL-GLL, 2005). However, this analysis assessed the public health and safety of the Adaptive Phased Management Approach across the three phases of the project (refer to Section 2).

5.3.1 Number of Workers at Risk

Table 5.3-1 provides an estimate of the total direct employment, expressed as full time equivalents (person-years), for Adaptive Phased Management and is based on cost estimates for this approach. With the exception of transportation activities, the estimated employment is independent of the ER. Estimates of total direct employment are based on an approximate average annual labour cost of $120,000 per person-year. This value has been derived in reference to the CTECH cost studies (see Table 2-1).

TABLE 5.3-1:
ESTIMATED WORKFORCE FOR ADAPTIVE PHASED MANAGEMENT

	Placement of Used Nuclear Fuel		*Ongoing Management of Facility*[17]	
Management Approach	*Total Full Time Equivalents (person-years)*	*Period (year)*	*Total Full Time Equivalents (person-years)*	*Period (year)*
Adaptive Phased Management	27,206	1 - 59	71,069	60 - 325

Overall, a greater workforce is required for Adaptive Phased Management than for Deep Geological Disposal in the Canadian Shield. This reflects the active management of used nuclear fuel over approximately 300 years for Adaptive Phased Management. Deep Geological Disposal does however, have a larger workforce for the placement of used nuclear fuel. The workforce for the Adaptive Phased Management Approach is less than that for Storage at Nuclear Reactor Sites and Centralized Storage because periodic repackaging of used nuclear fuel is not required.

5.3.2 Risks Due to Radiation Exposure

The radiological impact for Adaptive Phased Management to workers under normal conditions and off-normal conditions were investigated and compared against the Canadian limits. Bounding case impacts were calculated for each phase of the Adaptive Phased Management Approach and are discussed as follows (see Table 5.3-2 for details).

[17] Monitoring will continue, but at a reduced level following closure of the long-term isolation facility in year 325. The number of workers required will be minimal and are not included in this analysis.

Phase 1: Preparing for Central Used Fuel Management

The worker safety assessment of Storage at Nuclear Reactor Sites was considered fully applicable to this phase. This is likely a conservative assumption as there will be no repackaging for the wastes during this phase.

Phase 2: Central Storage and Technology Demonstration

With respect to the initial handling of used nuclear fuel (receiving and repackaging), radiological impact from Phase 2 of the Adaptive Phased Management Approach will be similar to that from Centralized Storage. The bounding normal and off-normal scenarios for this phase were assumed to be similar to those for Centralized Storage (operation of the below ground facility, and failure of all 384 fuel bundles due to a drop of a dry storage container).

Phase 3: Long-Term Containment, Isolation and Monitoring

The bounding scenarios for Phase 3 were assumed to be similar to those for the Deep Geological Disposal in the Canadian Shield. However, due to the decay of radionuclides during Phase 2, the maximum annual doses to workers are likely to be lower than the estimated doses for the Deep Geological Disposal in the Canadian Shield option.

Summary of Results

During normal conditions, all radiation doses predicted for all three phases of Adaptive Phased Management are well below the regulatory criteria. All off-normal radiation doses are also well below the applicable criteria. The estimated doses are the maximum expected dose to any worker. Based on current experience at operating nuclear generating stations, it is expected that the average dose to workers during each phase would be considerably less.

TABLE 5.3-2: RADIATION DOSE TO WORKERS FROM BOUNDING CASES FOR ADAPTIVE PHASED MANAGEMENT

Adaptive Phased Management Phase	Bounding Case	Max Dose (mSv/y)	Probability	Estimated number of Workers Affected	Time of Peak Impact	Limit (mSv/y)	% of the Limit
Normal Conditions							
Phase 1	Operation of the fuel management facility	0.5	1	Site operators	During storage	20	2.5
Phase 2	Operation of the centralized storage facility	17	1	Operators and mechanics	During placement of used nuclear fuel into extended storage facility	20	85
Phase 3	Operation of the isolation facility	<17	1	Operators and mechanics	During placement of used nuclear fuel into isolation facility	20	<85
Off-normal Conditions							
Phase 1	Failure of all 384 fuel bundles due to a drop of a dry storage container	15	$<10^{-7}$	Nuclear energy workers	Placement of used nuclear fuel in storage	30 [a]	50
Phase 2	Failure of all 384 fuel bundles due to a drop of a dry storage container	15	$<10^{-7}$	Nuclear energy workers	Placement of used nuclear fuel into the storage facility	30 [a]	50
Phase 3	Failure of the shaft and hoisting facilities, along with ventilation failure	<20	$4x10^{-3}$	Nuclear energy workers	Placement of used nuclear fuel into isolation facility	30 [a]	<67

a - The CNSC has not specified a nuclear energy dose limit for accidental conditions. 30 mS*v* is used by OPG for potential accidents at a nuclear station.

5.3.3 Risks Due to Conventional Occupational Injury

The industrial injury and fatality rates presented in the Technical Report (GAL-GLL, 2005) are also applicable as a benchmark for the Adaptive Phased Management Approach. Table 5.3-3 presents the estimated number of injuries and fatalities for Adaptive Phased Management based on the nuclear power industry injury and illness rates [0.9 annual average Lost Time Accident Frequency Rate (LTAFR) and 3.7 annual average Total Recordable Accident Frequency Rate (TRAFR)]. Health and safety programs will be implemented as part of Adaptive Phased Management which will aim to minimize the actual number of injuries.

TABLE 5.3-3:
ESTIMATED WORK-RELATED INJURIES AND FATALITIES FOR ADAPTIVE PHASED MANAGEMENT

Management Approach	Placement of Used Nuclear Fuel			Ongoing Management of Facility		
	Estimated LTAFR	Estimated TRAFR	Period (year)	Estimated LTAFR	Estimated TRAFR	Period (year)
Adaptive Phased Management	245	1,006	1 - 59	640	2,630	60 – 325

5.3.4 Risks from Transportation

Off-site transportation is required in Phase 2 of Adaptive Phased Management. The analysis of radiological risks from transportation presented in the Technical Report (GAL-GLL, 2005) is applicable to Adaptive Phased Management. For normal conditions, all transportation scenarios are below the CNSC dose limit. (For the purpose of the assessment the limit is assumed to be one fifth of the CNSC cumulative 5 year limit of 100 mSv).

For off-normal scenarios, the worst credible accident was estimated to result in a dose of 190 mSv/y to members of the transport crew. This is higher than the dose constraint used for nuclear accidents in Canada; however the probability is low (1 x 10^{-5} per year) and the estimate is made using a conservative release scenario.

The conventional risks of transportation presented in Section 4 of this report, include the driver and are applicable to worker health and safety.

5.4 Summary of Worker Health and Safety Analysis

Worker health and safety relates to the conventional and radiological risks that workers may be exposed to as a result of implementing the used nuclear fuel management approaches. This includes risks associated with the transportation of used nuclear fuel and other operations associated with its long term management. The construction, operational and monitoring procedures should be such that, in addition to complying with good engineering practices and all industrial safety regulations, workers in any way involved with the used nuclear fuel facility will not be subjected to risks or harmful exposures greater than those acceptable to Canadian and international authorities at the time of construction.

The assessment used quantitative information available in the literature or capable of being estimated within the timeframe available for the assessment and builds on the approach used by the Assessment Team and GAL/GLL in similar studies. Information was developed for each of the approaches within each of the relevant illustrative ERs. This included the identification of the radiological and physical risks associated with each approach, including transportation. Current experience with respect to radiation exposures and occupational health and safety in similar industrial sectors provides a useful and appropriate basis for predicting and comparing the benefits and risks of implementing each of the approaches.

A summary of the worker health and safety analysis for this approach in terms of their benefits, risks and costs is discussed below. Following that, a rollup comparison of all four management approaches is detailed in Table 5.4-1.

Benefits

The Adaptive Phased Management Approach can be built and operated to meet applicable worker health and safety standards under normal and off-normal conditions, with the exception of the worst credible transportation accident. Most importantly, all of the activities required to implement the approaches involve current and proven procedures and practices, which have been demonstrated to be capable of being carried out safely without undue risk to workers.

The total size of the workforce anticipated for Adaptive Phased Management is larger than that required for Deep Geological Disposal but is much less than that required for Storage at Nuclear Reactor Sites and Centralized Storage. This is because the workforce for Adaptive Phased Management is required until Year 325, whereas the workforce for Deep Geological Disposal is only required until Year 154, and the other approaches require a workforce beyond Year 10,000.

The industrial accident rates predicted for the approach is typically less than in non-nuclear mining and construction projects. This assumption is based on the current safety record of the nuclear industry, including uranium mining.

Risks

Radiation exposures to workers during operations and transportation are within acceptable Canadian standards for this approach under normal and off-normal conditions. As noted, the highest radiation exposure to the greatest number of workers occurs during packaging and transportation; however, risks are within acceptable standards and occur before the closure of the underground facility. Transportation activities can be designed and carried out safely and meet all applicable criteria. Risks from off-normal transportation conditions increase with transportation distance. Accordingly, risks associated with transportation would be lowest for illustrative ERs that are located closest to the current reactor sites or regions.

Costs

The cost of this approach includes the total workforce costs which incorporate reasonable and predictable costs for worker safety. This includes the costs for worker radiation protection and conventional occupational health and safety programs and procedures for all management approaches through facility designs and monitoring programs.

TABLE 5.4-1: SUMMARY OF WORKER HEALTH AND SAFETY ANALYSIS – A COMPARISON OF MANAGEMENT APPROACHES: BENEFITS, RISKS AND COSTS

Measure or Indicator	Benefits	Risks	Costs
Number of Workers at Risk	• There are no benefits associated with this measure	• The size of the workforce for used nuclear fuel 'in place' (i.e., in the near-term) is approximately three times higher for Deep Geological Disposal in the Canadian Shield than for Storage at Nuclear Reactor Sites and Centralized Storage (above or below ground). • The size of the workforce for Adaptive Phased Management is larger than that for Deep Geological Disposal in the Canadian Shield because of the over 300 year active management of the used nuclear fuel. • The size of the workforce in the long-term for Deep Geological Disposal in the Canadian Shield and Adaptive Phased Management approaches is less than Storage at Nuclear Reactor Sites and Centralized Storage (above or below ground) because there is no repackaging of the wastes in the long-term. • There are no differences between ERs.	• Costs of employing the workforce are included in the economic costs of the management approaches as the labour cost for each stage.
Radiological Dose to Workers	• Radiation exposures to workers during operations and transportation are within acceptable Canadian standards for all management approaches for normal and off-normal conditions. • In the near-term, radiation dose to workers are lower for Storage at Nuclear Reactor Sites and Centralized Storage (above ground). • All radiation exposures to workers will be incurred in the first 154 years for Deep Geological Disposal in the Canadian Shield and in the first 325 years for Adaptive Phased Management.	• In the near-term, Deep Geological Disposal in the Canadian Shield and Adaptive Phased Management approaches require a greater number of workers being exposed to a higher radiation exposure than Storage at Nuclear Reactor Sites and Centralized Storage (above or below ground). • Risks are continuously incurred over the long-term for both Storage at Nuclear Reactor Sites and Centralized Storage (above or below ground), and are committing future generations of workers to repeated radiation exposure conditions due to repackaging events. • There are no differences between ERs.	• Some costs for worker safety, including radiation protection, are accounted for in the economic costs of all management approaches through facility designs and monitoring programs. • There are no differences between ERs.
Conventional Risks to Workers	• The anticipated industrial accident rate is expected to be less than in non-nuclear mining and construction projects due to a higher standard of care in the nuclear industry. • Storage at Nuclear Reactor Sites does not require transportation, and therefore has none of the associated transportation risks.	• A larger number of injuries are anticipated over the entire life of the project for Centralized Storage (above or below ground) and Storage at Nuclear Reactor Sites due to the repetitious repackaging of used nuclear fuel over 10,000 years. • More injuries are anticipated for used nuclear fuel 'in place' for Deep Geological Disposal in the Canadian Shield and Adaptive Phased Management approaches than for Storage at Nuclear Reactor Sites and Centralized Storage (above or below ground). • Injuries and fatalities as a result of transportation depend on distance travelled; therefore there is a greater risk of injury for longer transportation routes than for shorter routes.	• Some costs for worker safety, including conventional occupational health and safety protection, are accounted for in the economic costs of all management approaches through facility designs and monitoring programs. • There are no differences between ERs.

6.0 ANALYSIS OF SECURITY

6.1 Context for the Analysis of Security

Objective: *The selected management approach needs to maintain the security of the nuclear materials and associated facilities. For example, over a very long timeframe, the hazardous materials involved ought to be secure from the threat of theft despite possibilities of terrorism or war* [18]*.*

6.2 Influencing Factors and Measures Used in the Analysis of Security

Similar to the analysis of the other three approaches in the Technical Report (GAL-GLL, 2005), the following influencing factors and measures are used in the assessment of the Adaptive Phased Management Approach:

Influencing Factors used in Preliminary Comparative Assessment	Influencing Factors used in this Analysis	Measures used in this Analysis
Impacts on non-proliferation	Impacts on non-proliferation	• Used nuclear fuel accessibility
Security of facilities	Security of facilities	• Number of used nuclear fuel-bundle repackaging cycles • Robustness of physical barriers • Number of population centres in the region
Security of nuclear materials	Considered as part of Security of facilities and Security of transportation and other support systems	
Security of transportation and other support systems	Security of transportation systems	• Transportation distance and number of shipments • Number of population centres along transportation corridor

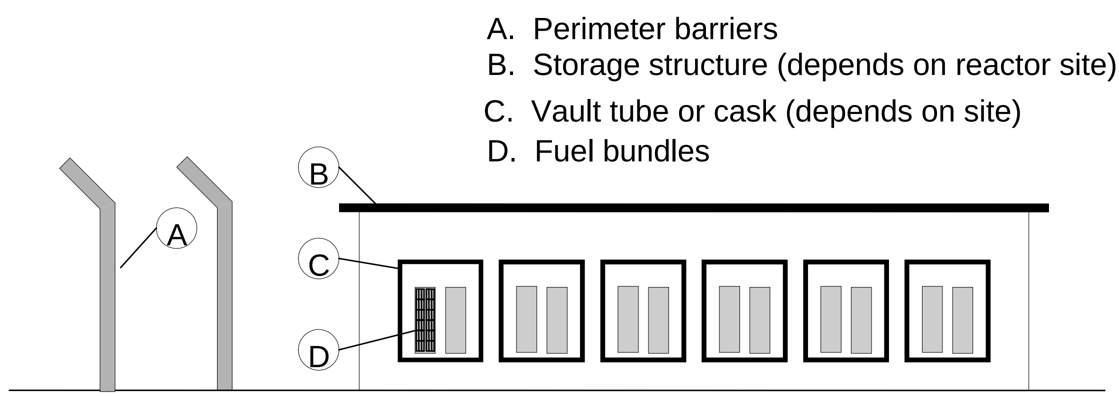
[18] Nuclear Waste Management Organization, *Understanding the Choices – The Future Management of Canada's Used Nuclear Fuel*, September 2004, page 65.

6.3 Methods and Details of Security Analysis

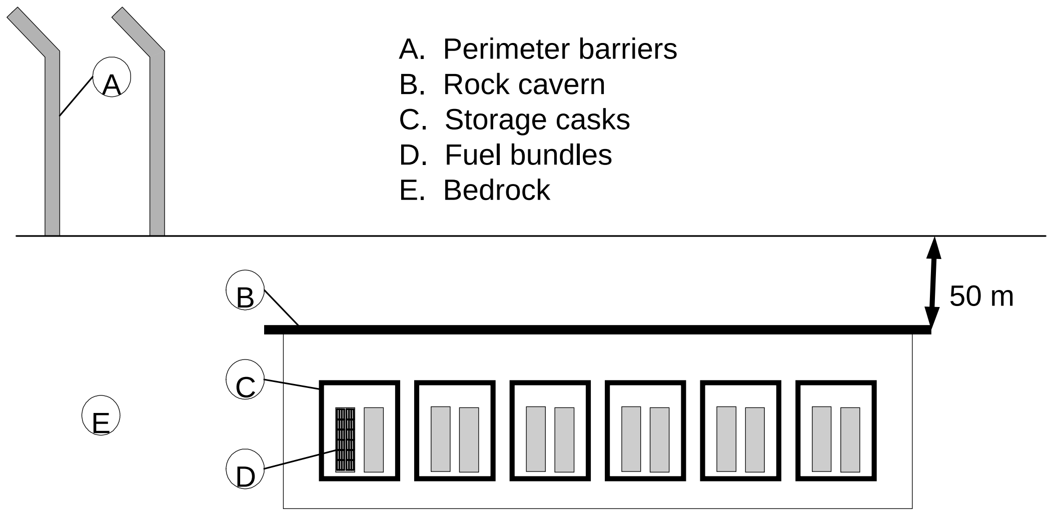
The methods and details used in the following analysis are generally similar to those used in the assessment of the other approaches. However, for the assessment of Adaptive Phased Management, the analysis considered security for the three phases of the project (refer to Section 2).

A depiction of the physical barriers at each stage of management is presented in Figures 6.3-1 to 6.3-3.

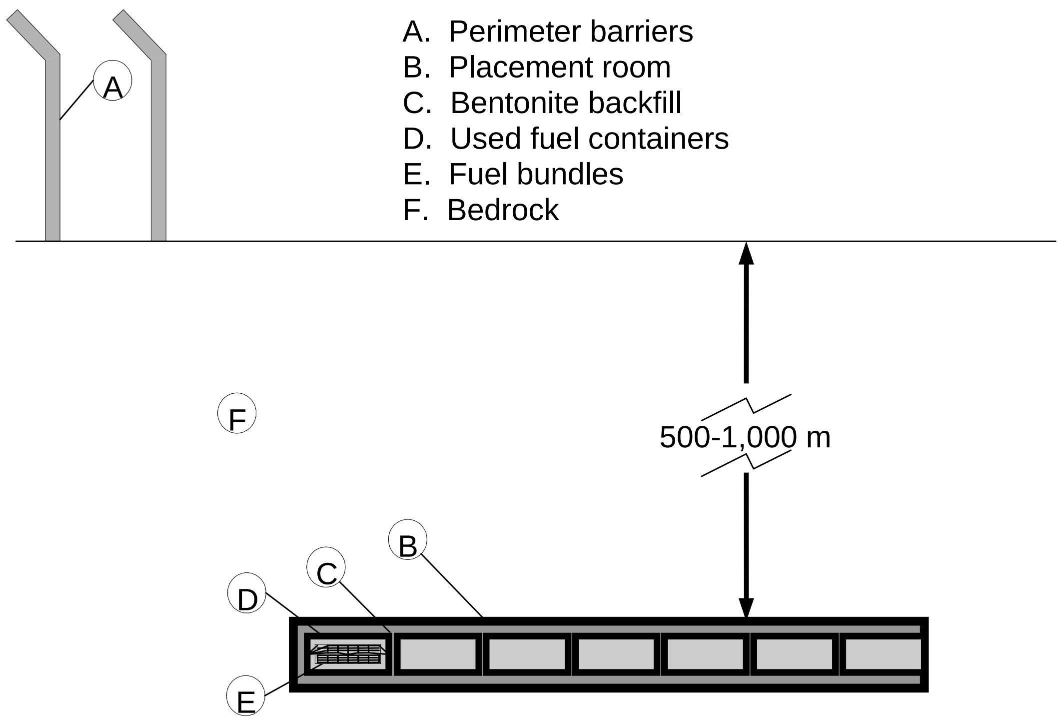
PHYSICAL BARRIERS – PHASE 1: USED NUCLEAR FUEL REMAINS IN INTERIM STORAGE | FIGURE 6.3-1



PHYSICAL BARRIERS – PHASE 2: CENTRAL FACILITY | **FIGURE 6.3-2**



PHYSICAL BARRIERS – PHASE 3: LONG TERM CONTAINMENT, ISOLATION, AND MONITORING	FIGURE 6.3-3



6.4 Results of the Security Analysis

This section presents the results of the analysis for each of the six measures described above.

Table 6.4-1 provides the results of the security analysis for three target richness measures: used nuclear fuel accessibility, number of repackaging cycles and robustness of physical barriers. "Richness measures" refers to the degree of opportunity provided for security breeches.

TABLE 6.4-1:
SITE INDEPENDENT - TARGET RICHNESS MEASURES FOR ADAPTIVE PHASED MANAGEMENT

Management Approach	Used Nuclear Fuel Accessibility			Number of Used Nuclear Fuel Repackaging Cycles over 10,000 yrs.			Robustness of Physical Barriers (Number and Type)		
	Phase 1 0-29 years	Phase 2 30-59 years	Phase 3 >60 years	Phase 1 0-29 years	Phase 2 30-59 years	Phase 3 >60 years	Phase 1 0-29 years	Phase 2 30-59 years	Phase 3 >60 years
Adaptive Phased Management	Low	Very low	Not readily accessible	0	1	1	Four engineered barriers	Four engineered barriers; One (deep) geologic barrier	Five engineered barriers; One (deep) geologic barrier and permanent closure

6.4.1 Used Nuclear Fuel Accessibility

The accessibility of the used nuclear fuel is generally low during storage at the reactor sites and is very low once the used nuclear fuel is placed in underground storage at the Central Facility. In the long term, the used nuclear fuel becomes relatively inaccessible because of backfilling of the rooms and sealing the access shafts after placement of the used nuclear fuel in permanent containers and closure of the facility (i.e., after year 325 of the project).

6.4.2 Number of Repackaging Cycles

The number of repackaging events required throughout the Adaptive Phased Management Approach is an important consideration in potentially allowing access to the used nuclear fuel and/or its dispersion into the environment. At the beginning of Phase 2, it is expected that a portion of the used nuclear fuel transported to the central facility would require repackaging upon receipt and prior to initial placement in the central facility. The repackaging would take place in an above-ground facility.

At the beginning of Phase 3, used nuclear fuel stored in dry storage containers is brought up to a surface facility and is repackaged into used nuclear fuel containers (refer to Figure 2-1), prior to isolation at depth.

Table 6.4-1 shows the number of repackaging and rebuilding cycles over the 10,000 year assessment period. The greater the number of repackaging events, the greater will be the overall vulnerability of the facility to terrorist attack. As noted above, the Adaptive Phased Management Approach involves two repackaging cycles, one beginning in year 30 when it is expected that a portion of the used nuclear fuel would require repackaging when it arrives at the central facility and is placed in dry storage containers, and one beginning in year 60 when the fuel is transferred from dry storage containers to used nuclear fuel containers for subsequent long-term isolation at depth.

6.4.3 Robustness of Physical Barriers

The type and number of physical barriers is important in restricting potential access to the used nuclear fuel throughout both the near and long term. As shown in Figures 6.3-1 through 6.3-3, each of the three phases involves at least four protective physical barriers including engineered barriers such as fences, sealed steel containers, reinforced concrete vaults and outer storage buildings. The geosphere is integral to storage and long-term isolation at the central facility (i.e., Phase 2 and Phase 3) and ensures an additional barrier(s) beyond that provided for by Interim Storage in Phase 1. This geologic barrier provides additional protection from attacks involving high-energy sources such as an aircraft, anti-tank missiles and military piercing weapons.

6.4.4 Number of Large Population Centres in the Region

The consequence of a terrorist attack that results in a radiological release will depend in part on the proximity of the release to population centres. The number of population centres of different sizes is listed for each of the four illustrative ERs in Table 6.4-2. Illustrative ERs with a number of large population centres (e.g., greater than 50,000 people) are assumed to present the greatest risk because of the greater number of people that would be potentially impacted from a terrorist attack. The risk would depend on the nature of the attack and the extent of dispersion of any radioactive materials; ERs with higher populations represent the largest risk.

TABLE 6.4-2:
POPULATION CENTRES BY SIZE WITHIN ILLUSTRATIVE ERS

Illustrative Economic Region	Number of Population Centres >50,000 within Illustrative ER
ER-2	0
ER-4	2
ER-5	0
ER-9	0

The results provided in Table 6.4-2 suggest that there is little difference in risk between illustrative ERs due to this measure.

6.4.5 Transportation Distance and Number of Shipments

Distance along major highways between each reactor site and the central point (geographic centroid) of each of the four illustrative ERs were totalled to estimate the transportation distance by road between reactor sites and the central facility. The routings used to determine the distances are shown on Figures 6.4-1 through 6.4-7 (see Appendix A).

The vulnerability of the used nuclear fuel is assumed to be in proportion to the transportation distance and the number of shipments along the route. The total number of trip-kilometres required to transport all the used nuclear fuel by road to a central facility is shown in Table 6.4-3. Similar results would be observed for transportation by rail or ship.

TABLE 6.4-3:
TRAVEL DISTANCE AND NUMBER OF SHIPMENTS BY ROAD FOR ADAPTIVE PHASED MANAGEMENT

Current Reactor Site	Whiteshell	Bruce	Pickering	Darlington	Chalk River	Gentilly	Point Lepreau	No. Shipments x Distance
Illustrative Economic Region	Number of Shipments							
	3	7812	4848	4852	30	767	665	
ER-2	1586 km	3575 km	3527 km	3556 km	3429 km	3947 km	4728 km	69 million
ER-4	1409 km	874 km	825 km	853 km	728 km	1245 km	2026 km	17 million
ER-5	3961 km	57 km	246 km	303 km	656 km	894 km	1675 km	5 million
ER-9	2850 km	2035 km	1856 km	1829 km	1628 km	1786 km	2567 km	37 million

Results indicate that the ERs representative of a long transportation distance, namely, ER-2 and ER-9, have the highest number of trip-kilometers and thus would be more vulnerable to a terrorist attack than ERs representative of a shorter transportation distance, such as ER-5.

6.4.6 Number of Large Population Centres along Transportation Route

The vulnerability of used nuclear fuel shipments to a terrorist attack with the objective of radiological release and dispersion also may be influenced by population density along the transportation route[19]. Illustrative ERs with the higher number of large population centres along the transportation routes would present the greatest risk because of the number of people that would be potentially impacted from a terrorist event.

[19] Wiles, R. and Cox, J.R., *Nuclear Waste Accident Scenarios in the United States*, June 27, 2002.

For this analysis, the number of different population centre sizes in each ER along the transportation route was totalled based on the identified routes shown on Figures 6.4-1 through 6.4-7 (see Appendix A). The number of unique population centres for the complete transport route from all seven reactor sites to each of the four illustrative ERs was determined.

Table 6.4-4 identifies the number of population centres greater than 50,000 people located within ERs that are crossed by road transportation routes between the reactor sites and the illustrative ERs.

**TABLE 6.4-4:
NUMBER OF POPULATION CENTRES ALONG TRANSPORTATION ROUTE WITH POPULATION >50,000 FOR ADAPTIVE PHASED MANAGEMENT**

Illustrative Economic Region	No. of Population Centres >50,000 along Transportation Route
ER-2	22
ER-4	19
ER-5	19
ER-9	20

Results indicate that the total number of population centres greater than 50,000 people along the transportation route for the different ERs ranges from 19 to 22. This suggests that there is little difference in the risk between ERs due to this measure.

6.4.7 Qualitative Description of Other Factors

Information related to Adaptive Phased Management is different for one of the three influencing factors (i.e., risk scenarios) that were described in Section 6.4.7 in the Technical Report (GAL-GLL, 2005):

- Societal breakdown - There is a risk that security could be compromised as a result of societal breakdown and, for example, abandonment of the facility by security personnel. In the longer term, it is likely that society and institutional stability will change. However, for Adaptive Phased Management, once the facility is decommissioned and closed (at the end of year 325), there would be no direct risk from such events.

6.5 Summary of Security Analysis

Six measures related to security were analyzed in detail for the Adaptive Phased Management Approach and have been analyzed previously for the other three Approaches in the Technical Report (GAL-GLL, 2005).

A summary of the security analysis for this management approach in terms of its benefits, risks and costs is discussed below. Following that, a rollup comparison of all four management approaches is presented in Table 6.5-1.

Benefits

The Adaptive Phased Management Approach is capable of providing a high degree of security from threats of theft despite possibilities of terrorism or war. This high level of security is achieved by restricting the accessibility of used nuclear fuel in the near and long term through the construction of engineered and geologic barriers. These barriers prevent terrorists for gaining access to the used nuclear fuel and/or causing radioactivity to be dispersed into the environment. The barriers are independent of ER.

The Adaptive Phased Management Approach limits the number of times the used nuclear fuel needs to be repackaged, thereby reducing opportunities for terrorism or security breeches.

In the near term, at least four independent engineered barriers are present which prevent accessibility of used nuclear fuel. (In the long-term, the deep isolation provides at least six independent engineered or geological barriers).

Risks

This approach still requires off-site transportation with its associated risk of security breeches. However, engineered barriers and security barriers are available to ensure these risks remain low. Further, risks associated with transportation would be lowest for ERs that are located closest to the current reactor sites.

As ERs in rural or remote regions have lower population densities and a smaller number of large population centres (>50,000 inhabitants), a central facility located there would have a lower risk because of a lower number of people that would be potentially impacted from a terrorist event.

In the long term, the Adaptive Phased Management Approach offers additional security because of the geologic barriers and permanent closure. Also, in the longer term, this approach, along with Deep Geological Disposal in the Canadian Shield, offers the greatest security in the event of societal breakdown.

Costs

Some of the costs for security are accounted for in the cost of the Adaptive Phased Management Approach. However, recent international events indicate that security features can be breeched and additional costs may be required in future to address as yet unspecified risks.

TABLE 6.5-1: SUMMARY OF SECURITY ANALYSIS – A COMPARISON OF MANAGEMENT APPROACHES: BENEFITS, RISKS AND COSTS

Measure or Indicator	Benefits	Risks	Costs
Fuel Accessibility (relates to nuclear non-proliferation)	• Deep Geological Disposal in the Canadian Shield and the Adaptive Phased Management approaches are inherently more secure than Storage at Nuclear Reactor Sites or Centralized Storage (above or below ground) as used nuclear fuel is relatively inaccessible in the long term because of backfilling and closure of facilities in years 154 and year 325, respectively. • While offering more security than Storage at Nuclear Reactor Sites and Centralized Storage (above and below-ground), Adaptive Phased Management is marginally less secure than Deep Geological Disposal in the Canadian Shield since it involves one additional repackaging event. • These benefits are independent of ER.	• Risk that security could be compromised and used nuclear fuel could become accessible as a result of societal breakdown in the future. In the long term, it is likely that society and institutional stability will change. Centralized Storage (above or below ground) and Storage at Nuclear Reactor Sites could be at risk in such an event(s); unlike Deep Geological Disposal in the Canadian Shield and the Adaptive Phased Management approaches there is no direct risk following closure. • These risks are independent of ER.	**For all six measures:** • Some costs for security are accounted for in the economic costs of all four approaches through facility designs and monitoring programs. However, recent international events indicate that security standards can be breached. With the passage of time, it may be necessary to change current security standards and activities to account for changing world events. This may dramatically change future security requirements and its attendant costs.
Number of Repackaging Cycles (periodic over time)	• Deep Geological Disposal in the Canadian Shield and the Adaptive Phased Management approaches do not require repackaging of used nuclear fuel once all used nuclear fuel is placed in the repository (year 59 and year 89, respectively) and are significantly more secure in the long term, compared with Storage at Nuclear Reactor Sites and Centralized Storage (above or below ground), which require 100 repackaging cycles over the 10,000 year assessment period. • Adaptive Phased Management has the same high level of security in the long term as Deep Geological Disposal in the Canadian Shield as neither have repackaging events in the long term. • These benefits are independent of ER.	• Repackaging of used nuclear fuel presents some risk of hostile attack for all four approaches. Storage at Nuclear Reactor Sites and Centralized Storage (above or below ground) have 100 repackaging cycles over the 10,000 year assessment period, which represents a significantly greater security risk than for Deep Geological Disposal in the Canadian Shield and the Adaptive Phased Management approaches over the long term. • These risks are independent of ER.	
Robustness of Physical Barriers (to protect the used nuclear fuel)	• Centralized Storage (below-ground), Deep Geological Disposal in the Canadian Shield and the Adaptive Phased Management approaches offer some security advantages over Centralized Storage (above-ground) and Storage at Nuclear Reactor Sites in the near and long term because they have more physical barriers (including geological barriers) and management below ground. • The greater depth of the Deep Geological Disposal in the Canadian Shield and the Adaptive Phased Management approaches, as well as permanent closure in year 154 or year 325, respectively, provide even further security in the long term. • The Adaptive Phased Management has the same number and robustness of physical barriers as Deep Geological Disposal in the Canadian Shield following facility closure in year 325 and 154, respectively. • These benefits are independent of ER.	• Engineered and geological barriers provide security against hostile interventions and dispersion of nuclear material in the near and long term. All approaches include at least four engineered barriers, but security risk could result from societal breakdown in the future (e.g., abandonment of the facility by security personnel). In the long term, it is likely that society and institutional stability will change. Both Centralized Storage (above or below ground) and Storage at Nuclear Reactor Sites could be at risk in such an event(s). Deep Geological Disposal in the Canadian Shield and the Adaptive Phased Management approaches have no direct risk from such an event(s), post closure. • These risks are independent of ER.	

Measure or Indicator	Benefits	Risks	Costs
Number of Large Population Centres (within illustrative ER)	• Deep Geological Disposal in the Canadian Shield and the Adaptive Phased Management approaches have the lowest number of large population centres (defined as greater than 50,000 inhabitants and based on available information) with a range of 0 to 2 large population centres across the respective four illustrative ERs for each of these two approaches, and have a lower relative risk related to this measure compared with the other two approaches, assuming current population distributions continue. Centralized Storage (above or below ground) has a range of between 0 and 8 large population centres across the six illustrative ERs while Storage at Nuclear Reactor Sites has a range of between 1 and 8 large population centres across the six illustrative ERs. • As ERs in the Canadian Shield tend to have lower population densities and smaller population centres, it follows that Deep Geological Disposal in the Canadian Shield has a lower number of large population centres across the illustrative ERs. In a similar manner, Adaptive Phased Management has the majority of its illustrative ERs in the Canadian Shield.	• Storage at Nuclear Reactor Sites includes long-term storage of used nuclear fuel at seven reactor sites across six ERs, compared with only one site in one ER for each of the other three approaches. The greater number of storage facilities for Storage at Nuclear Reactor Sites combined with the fact that these ERs have large population centres (between 1 and 8 each) present a greater security risk than the other approaches. • Although Deep Geological Disposal in the Canadian Shield and the Adaptive Phased Management approaches have a lower number of large population centres across the illustrative ERs at present, population growth and settlement patterns could change in the future and result in different population distribution across ERs, with changes in the number of large population centres over the long term.	
Transportation Distance and Number of Shipments (between locations in the near term)	• Storage at Nuclear Reactor Sites does not require off-site transportation of used nuclear fuel. Accordingly, there are no opportunities for attempted dispersion during transportation, which is a significant benefit of Storage at Nuclear Reactor Sites compared with the other three approaches in the near term. • Centralized Storage (above or below ground), Deep Geological Disposal in the Canadian Shield and the Adaptive Phased Management approaches would require additional safety requirements for the movement of the used nuclear fuel from the nuclear reactor sites to the storage facility (ies).	• For Centralized Storage (above or below ground), Deep Geological Disposal in the Canadian Shield and the Adaptive Phased Management approaches, the total number of trip-kilometres required to transport all used nuclear fuel by road to a facility vary considerably (by up to 15 times the number of trip-kilometres), depending on the illustrative ER. Vulnerability of the used nuclear fuel is assumed to increase with increases in the number of trip-kilometers, representing a greater security risk during transportation for illustrative ERs located longer distances from majority of used nuclear fuel (i.e., longer distances from southern Ontario).	
Number of Large Population Centres along Transportation Route (across ERs on transportation route)	• As Storage at Nuclear Reactor Sites does not require off-site transportation of used nuclear fuel, there are no opportunities for attempted dispersion during transportation, a significant benefit of Storage at Nuclear Reactor Sites compared with the other three approaches in the near term. • Centralized Storage (above or below ground), Deep Geological Disposal in the Canadian Shield and the Adaptive Phased Management approaches would require additional safety requirements for the movement of the used nuclear fuel from the nuclear reactor sites to the storage facility (ies).	• Centralized Storage (above or below ground), Deep Geological Disposal in the Canadian Shield and the Adaptive Phased Management approaches have a similar number of large population centres (defined as greater than 50,000 inhabitants and based on available information) along transportation routes for all of the illustrative ERs (i.e., between 19 and 22) and thus have a similar degree of security risk for this measure in the near term.	

7.0 ANALYSIS OF ECONOMIC VIABILITY

7.1 Context for the Analysis of Economic Viability

Objective: *Economic viability refers to the need to ensure that adequate economic resources are available, now and in the future, to pay the costs of the selected approach. The cost must be reasonable. The selected approach ought to provide high confidence that funding shortfalls will not occur that would threaten the assured continuation of necessary operations*[20].

The Adaptive Phased Management concept is in the early stages of development. Cost estimation considerations for this approach are described in Section 2.4. Conceptual design and cost estimates for Adaptive Phased Management have not yet been completed, and the concept assessed herein is essentially a compilation of appropriate existing components from the previously developed Centralized Storage - Casks in Rock Caverns (CES-CRC) concept [21] and the previously developed Deep Geological Repository (DGR) concept [22]. It is recognised that costs and schedules developed in this fashion are only preliminary and that future studies will likely optimize schedule and financial aspects.

As noted in Section 2, the Adaptive Phased Management concept is currently based on three distinct project phases:

- Phase 1: Preparing for Used Fuel Management (~ 30 years)
- Phase 2: Building the Central Facility and Demonstrating Technology (~ 30 years)
- Phase 3: Long-Term Containment, Isolation and Monitoring (~ 250+ years)

7.2 Influencing Factors and Measures Used in the Analysis of Economic Viability

The influencing factors and measures used in the analysis of Adaptive Phased Management are the same as those previously used in the analysis of the other approaches, with the addition of the total costs for each of the three phases, as shown below.

[20] Nuclear Waste Management Organization, *Understanding the Choices – The Future Management of Canada's Used Nuclear Fuel*, September 2004, pg. 69.
[21] CTECH Radioactive Materials Management, *Conceptual Designs for Four Centralized Extended Storage Facility Alternatives for Used Nuclear Fuel*, April 2003.
[22] CTECH Radioactive Materials Management, *Conceptual Design of a Deep Geological Repository for Used Nuclear Fuel*, December 2002.

Influencing Factors used in Preliminary Comparative Assessment	Influencing Factors used in this Analysis	Measures used in this Analysis
Expected Costs	Total Life Cycle Costs	Total Costs for each of the project phases: • Phase 1: Preparing for Used Fuel Management • Phase 2: Building the Central Facility and Demonstrating Technology • Phase 3: Long-Term Containment, Isolation and Monitoring Total Costs for each of the project stages: • Interim Storage and Retrieval • Representative Transportation • Siting/Approval, Design & Construction, Initial Operations • Monitor, Operate and Rebuild Transportation cost: • Average by Road • Incremental by Road

Financial Resources	Time period where expenditures are required	Costs over time:
		• Annual costs for 1,000 years
		• Cumulative total costs to 60, 175, 1,000, and 10,000 years
		• Total costs across time periods
		  • 1 - 30 years
		  • 31-175 years
		  • 176 - 1,000 years
		  • 1,001 – 10,000 years
		• Present value of annual costs

Cost Uncertainty	Cost Uncertainty	Contingency Costs across project stages: • Interim Storage and Retrieval [23] • Representative Transportation • Siting/Approval, Design & Construction, Initial Operations • Monitor, Operate and Rebuild Consideration of issues related to the Robustness of Cost Estimates

[23] Financial liabilities to be funded through the *Nuclear Fuel Waste Act* Trusts do not include Interim Storage and Retrieval Costs. While these costs add to the total liability of the Joint Waste Owners, and possibly impact their future capacity to borrow money, they are not an element of the cost estimate database or the responsibility of the Nuclear Waste Management Organization.

7.3 Results of the Economic Viability Analysis

The same methods were used in the analysis of Adaptive Phased Management as were used in the assessment of the other three approaches, as presented in the Technical Report (GAL-GLL, 2005). However, the economic viability of Adaptive Phased Management was also assessed across the three phases specific to the approach (refer to Section 2).

7.3.1 Total Costs for each of the Project Phases

Table 7.3-1 provides the total costs for Adaptive Phased Management across each of its three phases.

TABLE 7.3-1:
COSTS AND TIME PERIODS FOR ADAPTIVE PHASED MANAGEMENT PROJECT PHASES

Phase	Time Period (Year No.)	COSTS ($K 2002)[1]
Phase 1: Preparing for Used Fuel Management	1-29	$3,117,636
Phase 2: Building the Central Facility and Demonstrating Technology	30-59	$8,450,965
Phase 3: Long-Term Containment, Isolation and Monitoring[2]	60-325	$12,789,373
TOTAL		**$24,357,974**

[1] Includes applicable interim storage, retrieval and transportation costs
[2] This approach does not have a 'rebuild' component and is decommissioned and closed by year 325; costs for postclosure monitoring (estimated allowance of approximately $45 Million – present value equivalent ($2002) at year 326) not included.

7.3.2 Total Costs for each of the Project Stages

To allow a comparison with the other three management approaches, costs for Adaptive Phased Management are also considered over four project "stages", comparable with the "Total costs for each of the project stages" measure used previously for other approaches. It is noted that these four stages do not necessarily represent a well-considered segmentation of Adaptive Phased Management costs.

Table 7.3-2 presents the costs assigned to the four comparative project stages. These costs are used to estimate the economic benefits of the implementation of the management approaches in the illustrative ERs.

TABLE 7.3-2:
COSTS AND TIME PERIODS FOR COMMON PROJECT STAGES FOR ADAPTIVE PHASED MANAGEMENT

Project Stage	Time Period (Year No.).	COSTS ($K 2002)
Interim Storage and Retrieval	1-59	$2,380,000
Representative Transportation	30-59	$1,151,492
Siting/Approval, Design & Construction, Initial Operations[1]	1-59	$8,039,496
Monitor, Operate and Rebuild (One Cycle)[2]	60-325	$12,786,986
TOTAL - End of One Cycle (approximate)		**$24,357,974**

[1] End of this project stage referred to in Section 8 and below as used nuclear fuel ‘in place’.
[2] This approach does not have a ‘rebuild’ component and is decommissioned and closed by year 325; costs for postclosure monitoring (estimated allowance of approximately $45 Million – present value equivalent ($2002) at year 326) not included.

7.3.3 Transportation Cost

For the Adaptive Phased Management Approach, distances along major highways between each reactor site and the central point (geographic centroid) of each illustrative ER were totalled to determine the average road distance between current reactor sites and each illustrative ER. The distances are shown on Figures 6.4-1 through 6.4-7 (see Appendix A). The estimated incremental transportation costs for the four illustrative ERs are shown in Table 7.3-3. For comparison, the average road transport distance in the transportation cost estimate prepared by the Joint Waste Owners is 1,074 km.

The results in Table 7.3-3 show that the incremental road transportation distances to the illustrative ERs for Adaptive Phased Management range from an increase by approximately 2,500 km/trip (to ER-2) to a decrease by approximately 800 km/trip (to ER-5). These correspond to incremental transportation costs ranging from an increase of approximately $750 Million to a decrease of approximately $250 Million, respectively.

The incremental transportation costs are significant compared with the cost of the management approaches in the near term. Specifically, the incremental transportation cost for all illustrative ERs would range from a marginal decrease to an increase of up to 5% of the total facility cost (refer to Table 7.3-4) in the near term.

TABLE 7.3-3:
ADAPTIVE PHASED MANAGEMENT - INCREMENTAL TRANSPORTATION COSTS FOR SPECIFIC ECONOMIC REGIONS – ROAD

		A	B	C = B-A	D = C/A x E
Destination Illustrative Economic Region	Representative Cost by Road ($K 2002)	Average Distance Assumed Rep. Cost by Road (km/trip)	Actual Road Distance Estimated (km/trip)	Total Incremental Road Distance (km/trip)	Incremental Cost (Cdn. 2002 $Million)
ER-2	$1,151,000	1,074	3,613	2,539	$757
ER-4	$1,151,000	1,074	911	-163	-$48*
ER-5	$1,151,000	1,074	260	-814	-242*
ER-9	$1,151,000	1,074	1,945	871	$259

E = Transport System Operation Cost Estimate ($320 Million) - reference: "Cost Estimate for Transportation of Used Fuel to a Centralized Facility. Report of a Study carried out for Ontario Power Generation, New Brunswick Power, Hydro Quebec and Atomic Energy of Canada Limited", Ref. 500276-B-010. Rev. 00, COGEMA LOGISTICS. September 22, 2003.
* = A negative number indicates a decrease in the transportation cost relative to the JWO representative cost, (Column A).

7.3.4 Costs Over Time

Annual and cumulative cost estimates over 1,000 years for Adaptive Phased Management are illustrated on Figure 7.3-1 (includes interim storage, retrieval and transportation costs) and Figure 7.3-2 (does not include interim storage, retrieval and transportation costs).

Cumulative total costs directly related to the Adaptive Phased Management facility are summarized in Table 7.3-4 for four time periods - these costs do not include interim storage and retrieval or representative transportation costs.

TABLE 7.3-4:
CUMULATIVE TOTAL FACILITY COSTS OVER TIME FOR ADAPTIVE PHASED MANAGEMENT

Time Period	Costs ($K 2002)
Up to 59 years (used nuclear fuel 'in place')	$8,039,496
Up to 175 years	$16,955,887
Up to 1,000 years[1]	$20,871,112
Up to 10,000 years[1]	$20,871,112

[1] – includes costs for postclosure monitoring (estimated allowance of approximately $45 Million – present value equivalent ($2002) at year 326)

Table 7.3-5 provides an additional breakdown of the costs by project stages, with the inclusion of Interim Storage and Retrieval and of Representative Transportation.

TABLE 7.3-5:
TOTAL COSTS ACROSS SPECIFIC TIME PERIODS BY PROJECT STAGE - ADAPTIVE PHASED MANAGEMENT

Time Period	Costs ($K 2002)
1 to 30 years	
Interim Storage & Retrieval	$932,212
Representative Transportation	$670,275
Facility Costs	$2,092,671
31 to 175 years	
Interim Storage & Retrieval	$1,447,788
Representative Transportation	$481,217
Facility Costs	$14,863,216
176 to 1,000 [1] years	$3,915,225
Total Projected in Trust at end of 2005 ($1,000)	$899,000

[1] – includes costs for postclosure monitoring (estimated allowance of approximately $45 Million – present value equivalent ($2002) at year 326)

7.3.5 Present Value of Annual Costs

The costs provided in Tables 7.3-1 through 7.3-5 are based on annual cash cost estimates in constant 2002 dollars. These non-discounted costs are provided for comparative purposes and allow an analysis of the differences between approaches by identifying near and long-term costs and costs over different project stages.

The analysis of alternative approaches to managing used nuclear fuel involves a comparison of costs over very long time periods. To fully appreciate how these costs "flow" over time, it is necessary to analyze the costs in real dollars, i.e., non-discounted terms[24]. By presenting real dollar costs over time, it is possible to visualize how the size and timing of cash requirements differ between management approaches, without concern for unpredictable inflationary or deflationary effects.

[24] "Real dollar costing" refers to the practice of costing future activities in terms of a common base year. Specifically, if one states that it will cost $1 million in real 2005 dollars to build a facility 10 years from now, it means that one has not accounted for the effect of inflation. It simply means that, if one were to build the facility today in 2005, it would cost $1 million, even though the plan is to do so in 10 years.

This practice of comparing non-discounted costs over time helps to interpret cost differences. It cannot realistically address the strategic question: *Given the differences in cost streams for each of the management approaches, which approach requires the least amount of investment dollars today to implement?*

It must be recognized that if two management approaches involve the same real dollar cash expenditures, but one is spent earlier than the other, then the latter (late-spending) approach is less costly to finance. For the late-spending approach, one can invest a smaller amount of cash in an interest earning bond, which can later be used to pay for future costs, as financial markets can be used to help create a portion of the cash required to meet the future cost obligations. Management approaches that require earlier expenditures have less time to generate interest income and therefore require greater up-front investment by the owner.

Total costs of different approaches can also be compared on the basis of present value, a method often utilized for financial planning purposes. Present value analysis accounts for the ***"time value of money***" (as exemplified above). The user stipulates a discount factor based on anticipated rates of return and cost inflation factors that are applied to future constant-dollar cash requirements. The higher the discount factor, the more reliant the analysis depends on interest earning income to pay for future expenditures.

The present value of the costs estimated for the Adaptive Phased Management Approach was estimated using the same inflation factors and discount rates (received via email from Paul Lovie, NWMO, on February 11, 2005) that have been previously used by the Joint Waste Owners in their estimation of present value for the other three management approaches. The estimated present value for Adaptive Phased Management, including interim storage, retrieval[25] and transportation costs, is approximately $6.1 Billion ($ January 2004).

7.3.6 Contingency Costs

The cost estimates completed by the Joint Waste Owners for the other three management approaches were excerpted and combined (refer to Section 2.4) to create estimates for the Adaptive Phased Management Approach. Because these cost estimates included contingency costs, as discussed in the Technical Report (GAL-GLL, 2005), additional contingency for Adaptive Phased Management has not been added.

A discussion of overall cost estimate robustness is provided in Section 7.3.7.

[25] Financial liabilities to be funded through the *Nuclear Fuel Waste Act* Trusts do not include Interim Storage and Retrieval Costs. While these costs add to the total liability of the Joint Waste Owners, and possibly impact their future capacity to borrow money, they are not an element of the cost estimate database or the responsibility of the Nuclear Waste Management Organization.

Contingency cost estimates for all activities other than interim storage and retrieval are available for the three phases of Adaptive Phased Management, as shown in Table 7.3-6.

TABLE 7.3-6:
CONTINGENCY COSTS ACROSS PROJECT PHASES FOR ADAPTIVE PHASED MANAGEMENT

Adaptive Phased Management		
Phase	**Contingency Costs (2002) $1,000[1]**	**% of Total Phase Cost**
Phase 1: Preparing for Used Fuel Management	$497,733	16%
Phase 2: Building the Central Facility and Demonstrating Technology	$1,320,680	16%
Phase 3: Long-Term Containment, Isolation and Monitoring	$2,476,904	19%

[1] Includes transportation. Contingency costs not available for interim storage and retrieval.

Table 7.3-7, shows estimated contingency amounts, where available, for the four comparative project stages. The contingency amounts are significant and are on the order of 13 to 21 % of the cost of each project stage.

Of note is that the Adaptive Phased Management Approach costs include an allowance for an extensive research and development program, including an underground research facility. Approximately $1.4 billion (2002) has been allocated for this program, anticipated to span approximately 45 years.

TABLE 7.3-7:
CONTINGENCY COSTS ACROSS PROJECT STAGES FOR ADAPTIVE PHASED MANAGEMENT

Stage	**Contingency Costs (2002) $1,000**	**% of Total Stage Cost**
Interim Storage and Retrieval	not available	
Representative Transportation	$153,839	13%
Siting/Approval, Design & Construction, Initial Operations	$1,664,971	21%
Monitor, Operate and Rebuild (one cycle)[1]	$2,469,617	19%

[1] - This approach does not have a ‘rebuild’ component and is decommissioned and closed by year 325.

7.3.7 Consideration of Issues Related to the Robustness of Cost Estimates

As noted, the cost estimates for Adaptive Phased Management are based on estimates prepared previously for similar activities for the other three management approaches. Issues related to the robustness of the cost estimates include the accuracy of the source cost estimates, the validity of the assumptions underlying the use of these source cost estimates, the degree of similarity between the conceptual design and what may eventually be implemented, and the ability to estimate costs far into the future. Further, cost estimates for items without similar pre-existing estimates (the extensive early research laboratory component, the readily reversible closure of rock caverns by plugging and flooding, and the monitoring of a decommissioned and closed deep repository in perpetuity) have no underlying conceptual design studies and, at this time, are solely allowances based on professional judgement.

Review of cost estimates for similar activities, upon which Adaptive Phased Management estimates are predominantly based, included a professional opinion[26] that "the accuracy of these estimates is assessed as within the range of plus and minus 33% including all the contingency allowances…[T]hese estimates are considered suitable for their purpose in assessing the magnitude of the cost of the scenarios and their alternatives…". It was also noted that these source estimates were Class 3 or 4 with respect to American Association of Civil Engineers Recommended Practice No. 1712-97, Cost Estimate Classification System, implying that the range of costs could, in fact, be as large as -30% to +40% relative to estimated values.

The compilation of costs for similar activities used to construct the majority of Adaptive Phased Management cost estimates necessarily decreases the accuracy of the estimates. This additional uncertainty cannot be reliably quantified at the present time. The Adaptive Phased Management concept and related cost estimates have not been reviewed by independent third parties, nor have they been reviewed by the professionals responsible for the cost estimates that were excerpted and combined to create an assessable basis for the Adaptive Phased Management Approach.

Based on the addition of costs without consideration for synergies in contemplated activities and on the conservatism used in setting allowances, current estimates of Adaptive Phased Management costs may be biased high. However, during final design, siting, and environmental assessment and licensing, modifications to the design or schedule could also result in greater-than-predicted costs. For example, delays, litigation, changes to regulatory policy, changes to the licensing and approval process, changes to applicable standards, changes to security requirements, changes to environmental assessment and effects mitigation requirements and many other possibilities unforeseeable by present-day designers can easily lead to costs in excess of original estimates, including contingency.

[26] ADH Technologies Inc. & Charles River Associates Inc., *Validation of Cost Estimating Process for Long-Term Management of Used Nuclear Fuel*, prepared for the Nuclear Waste Management Organization, April 2004.

Moreover, long-term management cost estimates (i.e., those for activities hundreds of years from now) are based on current technology costs and assumptions as to the timing and frequency of events. Such costs should be considered order-of-magnitude only, even assuming future generations choose to continue long-term storage using current technology.

For these reasons, the cost estimate for the Adaptive Phased Management Approach should be taken as a general indication of possible costs suitable for comparing approaches and not as an accurate forecast.

7.3.8 Qualitative Analysis of Other Factors

As with all long-duration activities, there is a risk that major economic recessions and/or changes in the stability and competence of societal institutions could affect the economic viability of Adaptive Phased Management. Such events would have minimal effect on the Adaptive Phased Management postclosure (i.e., after year 325), as minimal financial resources and institutional involvement will be required in the long term and as small gaps in monitoring and/or institutional controls are unlikely to result in immediate adverse consequences once used nuclear fuel has been placed in long-term isolation. There is no clear difference in likelihood or severity anticipated across the different illustrative ERs.

Considerations regarding financial surety are as presented in the Technical Report (GAL-GLL, 2005). The Adaptive Phased Management Approach is assumed to involve extended operations across an approximate 300 year time period, which undermines the certainty with which appropriate financial surety can be determined. Sensitivity/potential for extreme events and unanticipated delays are as presented in the Technical Report (GAL-GLL, 2005).

7.4 Summary of Economic Viability Analysis

Seven measures related to economic viability were analyzed in detail for Adaptive Phased Management. A summary of the economic viability analysis for this approach in terms of benefits, risks and costs is discussed below. Following that, a rollup comparison of all four management approaches is presented in Table 7.4-1.

Benefits

The Adaptive Phased Management Approach, which has yet to be the subject of a conceptual design study and is currently at a preliminary level, is based on competent precedents and is structured to reduce risk while preserving real choice for future generations. For instance, deep waste isolation costs in the Adaptive Phased Management Approach are directly based on corresponding estimates for deep waste isolation costs for Deep Geological Disposal in the Canadian Shield. Unlike Deep Geological Disposal, however, the Adaptive Phased Management

Approach provides for viable ways to alter the implementation schedule for deep waste isolation or to forego it completely, as future generations decide based on the best information available (including future cost estimates).

Risks

Cost estimates are more uncertain the further into the future they are projected. Reasonable surety is also more difficult to assess for dates farther ahead in time. With respect to the time-dependence of estimate certainty and the provision of surety, Deep Geological Disposal in the Canadian Shield has the most certain estimates and is the easiest to develop surety for, as major activity ceases in year 154. The Adaptive Phased Management Approach is similar to Deep Geological Disposal in this respect since major activity can cease in year 325.

Costs

Using non-discounted cash flows for cost comparisons between management approaches is helpful in outlining the timing of the future costs. However, utilizing discounted cash flows to estimate the present value of costs of alternatives is a standard financial planning practice (see Section 7.3.5). The total (including interim storage, retrieval and transportation) present value cost estimate for the Adaptive Phased Management Approach is approximately $6.1 Billion ($ January 2004) compared with the present value cost estimates for Deep Geological Disposal in the Canadian Shield, Centralized Storage above and below ground, and Storage at Nuclear Reactor Sites, estimated previously by JWO as $6.2 Billion, $3.8 Billion, $3.4 Billion, and 4.4 Billion[27] respectively ($ January 2004).

A summary of estimated total (non-discounted) cash flows and estimated present value of costs completed by JWO and GAL-GLL for the four approaches is presented in Appendix B, including a variant of the Adaptive Phased Management Approach (without shallow underground storage at the central facility).

[27] *Storage at Nuclear Reactor Sites* taken as equivalent to JWO's *New Above Ground Technology*.

TABLE 7.4-1: SUMMARY OF ECONOMIC VIABILITY ANALYSIS – A COMPARISON OF MANAGEMENT APPROACHES: BENEFITS, RISKS AND COSTS

Measure or Indicator	Benefits	Risks	Costs
Total Costs for Each of the Project Stages Four stages: I -Interim Storage and Retrieval; II -Representative Transportation; III -Siting/Approval, Design & Construction, Initial Operations (i.e., all used nuclear fuel 'in place'); and IV - Monitor, Operate, and Rebuild (i.e., One Cycle)	• The economic benefits related to the implementation of the management approaches are discussed in Section 8 under *Community Economic Health*. • Deep Geological Disposal in the Canadian Shield has higher costs for Stages I and III, but much lower costs for Stage IV than Centralized Storage (above or below ground) and Storage at Nuclear Reactor Sites because the latter two include repackaging and rebuilding cycles, whereas the former is decommissioned after used nuclear fuel is placed into the underground repository (year 154). • The Adaptive Phased Management Approach has lower costs for Stage III, but higher costs for Stage IV than Deep Geological Disposal in the Canadian Shield. Adaptive Phased Management is also decommissioned after used nuclear fuel is placed into the underground repository and an extended monitoring period is completed (year 325). • These benefits are independent of ER.	• Risks are presented below in this table, under the measures: Contingency Costs Across Project Stages; Consideration of Issues Related to Robustness of Cost Estimates; and Qualitative Discussion of Other Measures	• There is a significant difference in cost between approaches for different project stages as shown by consideration of Stages I, III, and IV: • Deep Geological Disposal in the Canadian Shield and the Adaptive Phased Management approaches have the highest cost for Interim Storage and Retrieval (Stage I[28] - $2.4 billion – year 2002 dollars, not discounted). Storage at Nuclear Reactor Sites has the lowest cost ($1.3 billion – year 2002 dollars, not discounted). The Interim Storage and Retrieval Stage occurs up to year 59. • Deep Geological Disposal in the Canadian Shield has the highest cost for Siting/Approval, Design & Construction, Initial Operations (Stage III - $10.1 billion – year 2002 dollars, not discounted). Centralized Storage (below ground) has the lowest cost ($2.6 billion – year 2002 dollars, not discounted). The Siting/Approval, Design & Construction, Initial Operations stage occurs up to year 59. • Storage at Nuclear Reactor Sites has the highest cost for Monitor, Operate and Rebuild (One Cycle) (Stage IV - $17.6 billion – year 2002 dollars, not discounted). Deep Geological Disposal in the Canadian Shield has the lowest cost ($2.6 billion – year 2002 dollars, not discounted). This stage occurs up to year 154 for Deep Geological Disposal in the Canadian Shield and up to year 347 for the other approaches.

[28] Financial liabilities to be funded through the *Nuclear Fuel Waste Act* Trusts do not include Interim Storage and Retrieval Costs. While these costs add to the total liability of the Joint Waste Owners, and possibly impact their future capacity to borrow money, they are not an element of the cost estimate database or the responsibility of the Nuclear Waste Management Organization.

Measure or Indicator	Benefits	Risks	Costs
Transportation Cost (Incremental transportation cost over and above the representative transportation costs from current used nuclear fuel storage sites to a new facility site)	• There are no transportation costs associated with Storage at Nuclear Reactor Sites. A representative transportation cost for the other three approaches is in the range of $1.2 Billion (2002 dollars, not discounted).	• Risks are presented below, under the measures: Contingency Costs Across Project Stages; Consideration of Issues Related to Robustness of Cost Estimates; and Qualitative Discussion of Other Measures.	• The incremental transportation costs for Deep Geological Disposal in the Canadian Shield, Adaptive Phased Management and Centralized Storage (above or below ground) have a similar range and vary across economic regions by up to $900 Million (2002 dollars, not discounted). Incremental transportation costs are greater for economic regions located longer distances from the majority of the used nuclear fuel (i.e., southern Ontario). • For Deep Geological Disposal in the Canadian Shield, Adaptive Phased Management and Centralized Storage (above or below ground) across the illustrative ERs, the potential incremental transportation costs are significant compared with the cost of the management approaches in the near term.
Costs Over Time Considered on an annual and cumulative basis over a 10,000 year period, measured as: 1. Present Value (PV) Cost; and 2. Cumulative Annual Cost	• Centralized Storage (above or below ground) has a much lower present value cost compared with Storage at Nuclear Reactor Sites, Deep Geological Disposal in the Canadian Shield and Adaptive Phased Management; however, there is a significant difference in the time when these costs will be incurred between the four approaches. • Deep Geological Disposal in the Canadian Shield and Adaptive Phased Management have the majority of costs in the near term and a much lower cumulative annual cost over the 10,000 year assessment period compared with Centralized Storage (above or below ground) and Storage at Nuclear Reactor Sites.	• Risks are presented below, under the measures: Contingency Costs Across Project Stages; Consideration of Issues Related to Robustness of Cost Estimates; and Qualitative Discussion of Other Measures.	• The approximate present value cost estimates for each approach is as follows: Deep Geological Disposal in the Canadian Shield at $6.2 Billion; Centralized Storage (above/below ground) at $3.8/$3.4 Billion; and Storage at Nuclear Reactor Sites (new above-ground technology) at $4.4 Billion (all $ January 2004) as previously presented by JWO for the 3.7 Million Fuel Bundle case. The approximate present value cost estimate for Adaptive Phased Management is $6.1 Billion, based on the cost estimates developed for the present study and applying the same present value estimation methodology as JWO. • Cumulative costs vary significantly between approaches and during the time they are incurred: 1. Deep Geological Disposal in the Canadian Shield has the highest cumulative (non-discounted) cost[29] up to year 59, followed by Adaptive Phased Management, Storage at Nuclear Reactor Sites, and Centralized Storage (above or below ground). 2. The Adaptive Phased Management Approach has the highest cumulative (non-discounted) cost up to year 175, followed by Deep Geological Disposal in the Canadian Shield, Storage at Nuclear Reactor Sites, and Centralized Storage (above or below ground). 3. Storage at Nuclear Reactor Sites has the highest cumulative (non-discounted) cost up to year 1,000 and up to year 10,000, followed by Centralized Storage (above or below ground), Adaptive Phased Management, and Deep Geological Disposal in the Canadian Shield.
Contingency Costs Across Project Stages (Cost estimates include contingency)	• For all four approaches, near-term costs have accounted for some variability by including contingency in the cost estimates for every project stage (with the exception of interim storage and retrieval, for which no information on contingency was available). The contingency amounts are significant and are on the order of 20% for cost per project stage, with the exception of the transportation stage that includes approximately 13% contingency. As noted by others[30], even though the level of project detail is conceptual for Deep Geological Disposal in the Canadian Shield, Centralized Storage (above or below ground) and Storage at Nuclear Reactor Sites, with the added contingencies, the cost estimate accuracy is plus or minus 33%, which is typical of cost estimates prepared using conceptual design information. The cost estimate for Adaptive Phased Management is less accurate. • The contingency costs that have been added to each project stage for all four approaches are related to possible changes in costs for conceptual design. They are not related to other potential changes in the project scope such as changes in the final design of the management approaches or due to delays in project schedule. In addition, certain items are not typically considered in conceptual designs, such as costs for institutional strengthening within communities that may be affected by implementation of management approaches. As the implementation of a long-term management approach for used nuclear fuel in Canada is still in a planning phase, it is likely that in the future, the project scope will change and with it the estimated costs and related contingency cost requirements will change.		

[29] The cumulative costs do not include Interim Storage and Retrieval or Representative Transportation.
[30] ADH Technologies Inc. & Charles River Associates Inc., *Validation of Cost Estimating Process for Long-Term Management of Used Nuclear Fuel*, prepared for the Nuclear Waste Management Organization, April 2004.

Measure or Indicator	Benefits	Risks	Costs
Consideration of Issues Related to Robustness of Cost Estimates	• Cost estimates are more uncertain the farther into the future they are projected. Also, uncertainty with respect to surety increases for costs to be incurred further ahead in time. With respect to the time-dependence of estimate certainty and the provision of surety, Deep Geological Disposal in the Canadian Shield and Adaptive Phased Management have the most certain estimates as the vast majority of costs would be incurred in the near term. They are also the easiest to develop surety for because the facilities are decommissioned and closed by year 154 and year 325, respectively. The need for major rebuilding operations on a regular basis in perpetuity undermines the current generation's ability to estimate costs and provide surety with respect to Centralized Storage (above or below ground) and Storage at Nuclear Reactor Sites. Accordingly, Deep Geological Disposal and Adaptive Phased Management provide a higher confidence that funding shortfalls will not occur that would threaten the assured continuation of necessary operations compared with Centralized Storage (above or below ground) and Storage at Nuclear Reactor Sites.	• During final design, siting, environmental assessment and licensing, modifications to the design or schedule could result in significant cost increases for any of the four approaches. For example, the licensing and approval process, add-ons, more restrictive standards and other possibilities unforeseeable to the designers can easily lead to costs in excess of original estimates and the allowable contingencies. • Long-term management costs for the approaches (i.e., costs out to hundreds to thousands of years and beyond) are also based on current technology costs and assumptions as to frequency of events (e.g., repackaging). Such costs should be considered order-of-magnitude only, even assuming future generations choose to continue long-term storage using essentially 20th century technology. • It is not reasonable to assume that the financial markets of today will continue unchanged for the lifetime of the management approaches. Thus, elements related to interest rates, bond markets, financial institutions, and the ability to borrow are likely to change in the long term. However, it is reasonable to expect that the financial markets will likely remain intact in the near term, including the time period to put the used nuclear fuel 'in place' in a facility for any of the four approaches (i.e., 59 years). • Although existing cost estimates have been completed at the preliminary and conceptual design level as noted above, they should be taken as general indications of possible costs, and not as highly accurate forecasts, at least not beyond the near term.	• Not applicable for this measure

Measure or Indicator	Benefits	Risks	Costs

Qualitative Discussion of Other Measures

RISKS

- The cost estimates provided for Storage at Nuclear Reactor Sites and Centralized Storage, though useful for comparative purposes, have a higher degree of uncertainty than those for Deep Geological Disposal in the Canadian Shield and Adaptive Phased Management because they assume conditions far in the future.
- Costs for Centralized Storage (above or below ground) and Storage at Nuclear Reactor Sites impose a very large liability on future generations for continued management and in order to maintain the appropriate oversight institutions.
- Adaptive Phased Management spans a longer time period (i.e., to year 325) than Deep Geological Disposal in the Canadian Shield (i.e., to year 154) to also warrant examination of financial surety concerns.
- Concerns regarding financial surety exist because the following may change dramatically over the near term and the long term:
    - The financial viability of future utilities is not guaranteed; therefore, there is no guaranteed private source of revenues to pay future costs. However, government involvement helps ensure that a responsible authority will always manage and pay for the management of used nuclear fuel, assuming that our current governance structure remains in place.
    - One cannot predict how financial markets will be structured in the long term, let alone determine how current financing instruments (such as bonds, debt financing, etc.) might be used to finance cash requirements for management of used nuclear fuel.
    - The governance models within Canada may change over the long term – will there be a country called Canada that will ensure some form of continuity in management oversight? History shows there are few functional institutions today that are older than a thousand years. There is a high risk of loss of some management continuity.
    - How might used nuclear fuel management priorities be altered in possible future periods of social disorder or other "catastrophic" events? The consequences of such events would be much less significant for Deep Geological Disposal in the Canadian Shield and Adaptive Phased Management, post closure, as minimal financial resources and institutional involvement will likely be required in the long term, compared with the other two approaches, which will require significant financial resources and related institutional support for continued operation and rebuilding of infrastructure.
    - The known or proven technologies that provided the basis for the conceptual designs and cost estimates for the four approaches may be superseded or discarded with the passage of time. This would result in changes to future costs. For example, our ability to monitor environmental risks may become so advanced that we will discover the need to address environmental risks currently not considered, thus adding new costs to the management of used nuclear fuel. On the other hand, we may develop the ability to utilize used nuclear fuel as an input to other processes, thus making the used nuclear fuel a valuable resource.
    - Social values will change over time. The rapid and dramatic changes in social values over the past 100 years testifies to this. How we value the "natural environment", for example, will likely change. This means that levels of safety, and environmental and security risks that are considered "acceptable" today may become unacceptable in the future. In this scenario, used nuclear fuel may need to be retrieved and managed differently. In this case, additional financial resources may be needed for this "change in management" that are not currently accounted for in the cost estimates.
- In all the cases considered above, financial surety considerations of today become meaningless in the future. If one is only concerned about the ability to marshal the necessary financial resources to complete the management of used nuclear fuel, then this suggests a focus on Deep Geological Disposal in the Canadian Shield. This management approach places used nuclear fuel in a "final" state with relatively little financial requirements over the very long-term compared with Centralized Storage (above or below ground) or Storage at Nuclear Reactor Sites. This means that the burden of financial surety is placed mostly in the hands of the current generation. However, should some of the other social and/or technology issues arise, then future generations may be burdened with our used nuclear fuel legacy to an even greater extent.
- Adequate surety can be developed for Adaptive Phased Management. Examples exist of select human organizations and their investments persisting for over 325 years and Adaptive Phased Management provides for a long-term storage facility based on existing, passive technologies rooted in long-standing areas of human activity (mining, metallurgy). It is noteworthy that Adaptive Phased Management balances the risks that the required financial resources will be available when needed with the benefits of new technology development and proof of concept for long-term isolation in the near term. In addition, it preserves opportunities for decision making to future generations up to year 325 without compromising the responsibility of the current generation to identify a long-term solution.

8.0 ANALYSIS OF COMMUNITY WELL-BEING

8.1 Context for the Analysis of Community Well-Being

Objective: *The approach that is selected and the way it is implemented will determine the specific communities that are impacted and the nature of those impacts. For example, towns near the facilities required by the approach may be affected economically through impacts on jobs and property values. Differing attitudes within a community can lead to polarization that can severely degrade the social fabric. Nearby communities are not the only ones, however, that may be implicated. Many groups may feel that their shared interests are affected regardless of whether they live physically close to used nuclear fuel management facilities. Depending on the sites that eventually are proposed for consideration, Canada's Aboriginal peoples may have a particularly significant stake*[31].

8.2 Influencing Factors and Measures Used in the Analysis of Community Well-Being

Similar to the analysis of the other three approaches described in the Technical Report (GAL-GLL, 2005), the following influencing factors, measures, and indicators were used in the assessment of Adaptive Phased Management:

Influencing Factors used in Preliminary Comparative Assessment	Influencing Factors used in this Assessment	Measures and Indicators used in this Assessment
Community Economic Health	Community Economic Health	Using a customized Input/Output model the following indicators of community economic health were measured: • Employment • Income • Taxes
Community Social/Cultural Quality Effect on Impacted Community Social Quality	Community Social Quality Effect on Impacted Community Social Quality	Using the sustainable livelihoods framework, the following indicators of community social quality were measured: Non-Aboriginal Communities • Social Capital: – Population – Population density – Labour force composition – Mobility (inter, intra, and external)

[31] Nuclear Waste Management Organization, *Understanding the Choices – The Future Management of Canada's Used Nuclear Fuel*, September 2004, page 62.

Influencing Factors used in Preliminary Comparative Assessment	Influencing Factors used in this Assessment	Measures and Indicators used in this Assessment
		• Human Capital: – Educational achievement – Labour force – Unemployment – Life stress – self identified – Dependency ratio – Number of health practitioners – Number of health specialists – Self-rated health – Life expectancy – Infant mortality – Asthma readmission rates – Nutrition status • Financial Capital: – Income level – Incidence of low income – Labour force – Tenant households spending more than 30% of income on gross rent – Owner households spending greater that 30% of income on mortgage and upkeep – Number of occupied private dwellings • Physical Capital: – Number of dwellings that require major repair Use of public transportation
		<u>Aboriginal Communities</u> • Human Capital: – Percentage of the experienced labour force working in the health sector, social sciences, education, government service and religion – Educational achievement which was measured as the percentage of the population aged 20-34 with a high school graduation certificate and/or some postsecondary – Unemployment • Financial Capital: – Percent of population that own a primary dwelling – Median total income of persons aged 15 and older – Percent of labour force working in the business, finance and administration sectors • Physical Capital: – Percent of labour force using public transportation – Number of community access program sites – Number of School-net sites Another indicator used for developing the profiles for aboriginal communities is the ***Community Well-being index (CWB)***, which is based on four indicators (education, income, housing and labour force activity).

8.3 Results of Analysis of Community Well-Being

The analysis of community well-being was conducted using the same approach and methods as presented in the Technical Report (GAL-GLL, 2005). The analysis and discussion comparing the benefits, risks and costs of the Adaptive Phased Management Approach is presented in three sections as follows:

1. Analysis of community economic health;
2. Analysis of community social quality; and
3. Analysis of aboriginal community quality.

The discussion of benefits, risks and costs of Adaptive Phased Management is provided in relation to the three management approaches presented in the Technical Report (GAL-GLL, 2005).

8.3.1 Community Economic Health

As in the Technical Report (GAL – GLL, 2005), the community economic health impact was assessed using three measures, namely; employment, income and tax generation (to local communities). The Adaptive Phased Management Approach, like the other three approaches, would generate significant economic benefits in both the active management period (up to year 59) and the beginning of the long-term isolation period, as detailed in Table 8.3-1.

For Adaptive Phased Management, the near-term employment benefits to year 59 (used nuclear fuel 'in place') to the four illustrative ERs ranges from just over 91,000 jobs to nearly 159,000 jobs in the first 59 years of activity. The detailed analysis indicates that the annual employment benefits in the near term tend to peak in the later part of this period around 4,000-6,000 jobs per year.

During the approximately 266 year extended storage and monitoring period, employment benefits continue to average between 936 to 1,210 jobs per year generated.

In similar fashion, income (wealth) resulting from the Adaptive Phased Management Approach ranges from nearly $5 billion to nearly $7 billion in the near term to year 59 (used nuclear fuel 'in place'). This roughly translates into $100 million of income generation per year, within the four illustrative ERs.

Income continues to accumulate in each of the illustrative ERs until facility closure (year 325) to between $13.5 and $14.7 billion dollars. Both the employment and income benefits reported here accrue to each of the illustrative ERs. Additional and significant employment and income benefits would accrue to the associated host provinces and Canada as a whole.

The final measure of community economic health relates to amount of taxes generated for local communities that are within the four illustrative ERs. Between $124 and $349 million of taxes are generated for local communities to year 59 (used nuclear fuel 'in place'). This translates into some $2.4 to $6 million of local tax revenues per year. Over the longer term, local tax benefits amount to between $1.7 and $2.9 million across the four illustrative ERs.

These tax revenues, in combination with federal and provincial taxes can be used to fund infrastructure investments required to support the Adaptive Phased Management Approach, as well as investments in job training and other social needs.

TABLE 8.3-1: COMMUNITY WELL-BEING – ECONOMIC CONTRIBUTION OF ADAPTIVE PHASED MANAGEMENT IN FOUR ILLUSTRATIVE ECONOMIC REGIONS

	EMPLOYMENT (FTEs)											
	Employment (ER 4)			Employment (ER 5)			Employment (ER 9)			Employment (ER 2)		
	Direct	Indirect	Total	Direct	Indirect	Total	Direct	Indirect	Total	Direct	Indirect	Total
APMA - Waste in Place (Year 0- 59)	70,484	51,146	121,630	50,272	40,960	91,231	121,412	37,481	158,894	94,806	35,399	130,205
APMA - Operations, Monitoring & Closure (Year 60 - 325)	158,733	97,055	255,789	150,644	98,552	249,196	222,622	76,457	299,079	237,867	84,138	322,005
	INCOME ($000)											
	Income (ER 4)			Income (ER 5)			Income (ER 9)			Income (ER 2)		
	Direct	Indirect	Total	Direct	Indirect	Total	Direct	Indirect	Total	Direct	Indirect	Total
APMA - Waste in Place (Year 0- 59)	4,345,715	2,768,840	7,114,555	3,102,117	1,905,584	5,007,701	4,796,747	1,627,714	6,424,461	4,592,470	1,685,732	6,278,201
APMA - Operations, Monitoring & Closure (Year 60 - 325)	8,679,822	5,925,730	14,605,552	8,438,581	6,033,151	14,471,732	9,164,517	4,326,993	13,491,510	8,896,160	4,761,299	13,657,458
	TAX IMPACT ($000)											
	Taxes (ER 4)			Taxes (ER 5)			Taxes (ER 9)			Taxes (ER 2)		
	Federal	Provincial	Local	Federal	Provincial	Local	Federal	Provincial	Local	Federal	Provincial	Local
APMA - Waste in Place (Year 0- 59)	$1,317,454	$841,254	$176,909	$943,467	$602,633	$124,362	$1,500,832	$1,153,203	$314,414	$1,414,716	$836,049	$349,034
APMA - Operations, Monitoring & Closure (Year 60 - 325)	$2,639,231	$1,849,871	$455,718	$2,624,319	$1,840,725	$452,192	$3,085,755	$2,486,782	$646,454	$3,145,106	$1,928,190	$775,977

FTEs – Full Time Equivalents (i.e., person years of employment); All values for Income and Tax Impact are in 2002 dollars.

8.4 Community Social Quality

The Technical Report (GAL – GLL, 2005) described the capacity of how each of the four illustrative ERs are capable of adapting to the influx of economic activity resulting from the possible introduction of any one of the initial three used nuclear fuel management approaches. The possible introduction of Adaptive Phased Management does not change the analysis and discussion contained in the Technical Report (GAL-GLL, 2005), since that analysis was independent of management approach. The intent was to focus on the capacity of each illustrative ER to manage the opportunities and costs attendant with projects of this nature as well as address other social costs and benefits that are associated with large projects of this nature. The discussion of these social issues was qualitative in nature based on experiences derived from similar projects and published literature.

In reference to Table 8.5-5 of the Technical Report (GAL – GLL, 2005), it is instructive to note that ER-5 consistently scored higher (using the "Sustainable Livelihoods Measures") compared to the other three illustrative ERs in relation to its community well-being measures and index. This means that, under current conditions, ERs with similar socio-economic characteristics will be more capable of adapting to the challenges and opportunities posed by all four management approaches.

However, this is not to say that any of the ERs could not adapt. This analysis tends to indicate that the other less similar ERs will require additional resources and support to help them adapt to the challenges and opportunities offered by any of the management approaches. Such support may include for example; job training, infrastructure development assistance, property value protection, income assistance, housing assistance, and social services.

8.5 Aboriginal Community Quality

Like the social community quality analysis above, this analysis is independent of the management approach for used nuclear fuel. Again, the focus is on assessing how the aboriginal communities in the ERs are positioned to adapt to the opportunities and challenges that are linked to very large projects of this nature.

Generally speaking, ERs with similar aboriginal community characteristics to ER-5 would have a greater ability to adjust to the opportunities and challenges of any of the management approaches.

Implications for all Communities

In comparing illustrative ERs, we assume that the people within an ER have greater or lesser adaptive capacity based on the relative strength of the livelihood assets present in the ER. In the context of siting, designing, constructing and maintaining a nuclear waste management facility – a major change by any definition - the ER comparisons help to:

- Identify possible ways to support people and communities in building their livelihood assets;
- Identify ways to encourage responsive support from institutions and organizations; and
- Identify avenues that people and communities might choose to harness change for social and economic enhancement.

Economic regions with relatively low adaptive capacity will likely face significant challenges in the basic process of engaging with NWMO even in preliminary discussions of possible siting. The analysis points to the need for early measures to build the capacity of people within such ERs to effectively participate in discussions, dialogue and any required negotiations. Failure to employ early measures to build the capacity of people in ERs with relatively low adaptive capacity could easily be characterized as “unfair”.

People with the following attributes are unlikely to be able to engage fairly in discussions, dialogue and required negotiations:

- Focused on simply maintaining their livelihoods;
- Dealing with life stress;
- Caring for children and the elderly;
- Living on relatively low incomes;
- Living in sparsely populated areas where transportation and communication challenges are many;
- Do not have post-secondary qualifications;
- Have access to few experienced and employed professionals who could assist them in shaping discussions and required negotiations; and
- Have a variety of health challenges to deal with.

The same can also be said for the ability for such people to harness the social and economic opportunities represented by a nuclear waste management facility in their ER.

As a result, the siting of a nuclear waste management facility in an ER with low adaptive capacity will require that significant attention be devoted to working with the population and the institutions and organizations that serve the population, in order to identify meaningful and tangible ways for improving livelihoods and adaptive capacity.

Community values that may be negatively impacted include, to varying degrees, any of the following:

- Increased road congestion during construction;
- Increased noise, dust and other nuisances;
- Increase in the number of “transient” labour and other support workers;
- Changes in community “character”, such as the loss of a rural town atmosphere; and
- Change in rural/remote wilderness experiences if road or air access is increased.

The last two examples are most relevant if the deep geological deposit or the centralized storage approaches are located in rural or remote areas of Canada. Although these values are very important to local residents, they also hold some value to other Canadians located in urban centres. For example, residents of major population centres place some value on knowing “wilderness” and wildlife are protected, because they either wish to visit such areas or simply know that they exist for future generations. No attempt was made to measure these values in this study.

Community Costs:

There are a variety of costs that may arise within local and/or regional communities associated with any of the management approaches that add to overall costs, including but not limited to the following:

- Development of municipal infrastructure services to support increased labour and their families during peak construction periods;
- Requirement for added social services during and after peak development activities to help address rising stress on families and local businesses as they cope with possible job and business losses;
- Social stresses my include for example: increased crime and drug/alcohol abuse; and
- Property values tend to rise and fall in direct proportion to the level of development activity. This means, that certain property value protection measures will be required as has been the case in numerous other rural and remote communities linked to single industry development activities.

8.6 Summary of Community Well-Being:

Community well-being was analyzed in three sections for Adaptive Phased Management in this report, similar to the analysis completed previously for the other three Approaches in the Technical Report (GAL-GLL, 2005).

A summary of the community well-being analysis for Adaptive Phased Management in terms of the benefits, risks and costs is discussed below. Following that, a rollup comparison of all four management approaches is presented in Table 8.6-1.

Benefits

The Adaptive Phased Management Approach offers significant employment, income and tax benefits to all four illustrative ERs and their host provinces. The majority of these benefits occur in the near term.

Communities most affected by the investment in the Adaptive Phased Management Approach will require some degree of assistance to help avoid or mitigate social costs that are often associated with projects of this nature. If such measures are implemented in a timely and effective manner, community economic and social values will be greatly enhanced.

Risks

The various social and economic costs identified in this report are typical of boom and bust cycles in small or rural communities. If located in more urban centres, the risk of these economic and/or social costs are often less severe compared to rural or remote centres.

Costs

It must be recognized that failure to adequately invest in community(s) social, human, physical, financial, and environmental capitals, will lead to a host of economic and social costs. These costs have not been accounted for in the cost estimates for the Adaptive Phased Management Approach.

TABLE 8.6-1: SUMMARY OF COMMUNITY WELL-BEING ANALYSIS – A COMPARISON OF MANAGEMENT APPROACHES: BENEFITS, RISKS AND COSTS

Objective	Benefits	Risks	Costs

Community Well-Being
 	
Economic Health
 	
Influencing Factors:
- Income
- Employment
- Tax revenues
	• All four management approaches provide significant economic benefits. No matter which management approach is ultimately used and no matter what site location is preferred, economic benefits accrue to all Canadians, but the host Province and region stand to capture the majority of employment, income and tax benefits.
	• In the near-term (less than 175 years), both Deep Geological Disposal in the Canadian Shield and the Adaptive Phased Management approaches provide the greatest income, employment and tax benefits by up to a factor of two compared to Storage at Nuclear Reactor Sites, and by up to a factor eight compared to Centralized Storage (above or below ground).
	• Deep Geological Disposal in the Canadian Shield and Adaptive Phased Management are roughly equivalent in economic value to each illustrative economic region. However, the benefits of Adaptive Phased Management are stretched out over a longer time period (i.e. 30 years longer than Deep Geological Disposal in the Canadian Shield).
	• In the long-term (after year 175), only Storage at Nuclear Reactor Sites and Centralized Storage (above or below ground) generate any significant economic benefits from ongoing maintenance and cyclical facility rebuilding. Consequently, economic employment and income generating benefits continue for thousands of years. However, the most urbanized region tends to gain the most economic benefit in absolute terms.
	• Storage at Nuclear Reactor Sites is the only approach that simultaneously develops facilities at all seven current reactor sites, with benefits distributed to economic regions according to the size of their respective facilities and the volume of used nuclear fuel.
	• Centralized Storage (above or below ground), Deep Geological Disposal in the Canadian Shield and the Adaptive Phased Management approaches require significant expenditures for transportation, which add thousands of jobs and income to the whole of Canada, and is independent of site location.
		• Despite the very positive economic benefits resulting from all four management approaches, there are a variety of social and economic costs that are attendant with projects of this magnitude, particularly when sited in rural regions of Canada.
		• "Boom and bust" cycles linked to each of the management approaches involves thousands of workers and billions of expenditure dollars with the following likely effects:
		  • Housing and land values will rapidly spike at the outset of project implementation and will crash upon project completion, or while waiting for the next activity cycles;
		  • The large influx of short-term and temporary workers will increase demand for social and physical infrastructure services, which will become oversized and inefficient upon project completion; and
		  • Local and regional governments cannot count on sustainable financing and tax revenues to manage life-cycle replacement and costing management of all support services and infrastructure with large swings in labour force activity.
		• The predicted employment, income and tax benefits are based on a current interactive model of the Canadian economy using data from the 2001 census. It is certain that as technology, governance, and other social dynamics evolve, these predictions of employment, income and tax benefits will prove inaccurate. However, for the short-term projections, it is reasonable to use this method of economic forecasting.
			• Along with the economic benefits, each of the four management approaches bring a range of social and economic costs that must be managed. Such costs may likely include:
			  • Rising costs for basic services during the first phase of operations;
			  • Labour shortages and wage rate inflation also during the first phase of operations;
			  • With increased wealth and population growth, increases in crime and other social issues arise; and
			  • Change in the nature and character of communities in the region, particularly those that are in close proximity to the facility for Deep Geological Disposal in the Canadian Shield, Adaptive Phased Management or Centralized Storage (above or below ground).
			  • The impact on community character is likely to be less for Storage at Nuclear Reactor Sites since they already contain temporary used nuclear fuel handling facilities.
			• During the "bust" or decline period(s), social and economic costs abound, such as:
			  • Loss of personal and family wealth;
			  • Out-migration;
			  • Increased financial and personal stress;
			  • Business closures and loss of supporting services; and
			  • Increased crime and other social disorders.

Objective	Benefits	Risks	Costs

Community Well-Being
 	
Social Community Quality
 	
- Using the Sustainable Livelihoods Framework
 	
Four Capitals:
- Social Capital
- Human Capital
- Physical Capital
- Financial Capital
	• The more urbanized (populated) economic regions of Canada tend to score higher in their sustainable livelihood capitals. That is, they have more of the attributes and factors that make up each of the four capitals quantitatively measured in this study.
	• However, most of the technically feasible (ideal) locations for Deep Geological Disposal in the Canadian Shield occur in rural and remote regions that tend to contain fewer of the necessary capitals (facilities) to cope with the "shock" and/or take advantage of the opportunities offered by all four of the management approaches.
	• Adaptive Phased Management has somewhat greater flexibility in location and is not necessarily limited to remote regions of the Canadian Shield.
		• There is risk of inaction. Failure to act early on the investments in community capitals (human, social, physical, and financial capitals) may handicap these communities in their ability to participate in negotiations as well as participate in the benefits from increased employment opportunities.	• The costs are independent of management approach but tend to be greatest in rural and remote ERs.
			• The various costs identified in community economic health can be managed. But this requires long-term planning and investment in some or all of the Sustainable Livelihood Framework "Capitals".
			• The analysis of the all eleven illustrative ERs shows that there are distinct differences among the regions in relation to their capacity to adapt to the positive and negative "shock(s)" that are linked to all four management approaches.
			• It is evident that the more rural and remote regions have the lowest adaptive capacity. Some remote regions have at the present time very high unemployment rates, a lower educated workforce, higher life stresses and the least opportunities for self-improvement. Thus, should Centralized Storage (above or below ground) ,Deep Geological Disposal in the Canadian Shield, or the Adaptive Phased Management Approach be located in such a region, the local population is least capable (only in comparison to the other regions examined in this study) of adapting to the new employment opportunities. This might mean that employment opportunities may go to non-residents who might reside in the region only for the duration of the project activity.
			• The Sustainable Livelihoods Framework helps to:
			  • Identify possible ways to support people and communities in building their livelihoods assets in the face of incoming activities linked to all four management approaches;
			  • Identify ways to encourage responsive support from institutions and organizations; and
			  • Identify avenues that people and communities might choose to harness change for social enhancement.
			• Many of the rural and remote ERs examined in this study face significant challenges in the basic process of engaging with the NWMO even in preliminary discussions of possible siting. The analysis identifies the need for early measures to build the capacity of people within these rural and remote regions to effectively participate in discussions, dialogue and employment opportunities offered by each of the alternative management approaches.
			• A sample of the required investments in personal and community capitals in rural and remote regions includes the following:
			  • Job training programs;
			  • Affordable housing, property value protection;
			  • Financing assistance for needed infrastructure (e.g. roads, schools, recreational facilities, etc.;
			  • More health care services; and
			  • Management training and assistance in planning for the "boom/bust' cycle(s).

Objective	Benefits	Risks	Costs

Community Well-Being
Aboriginal Community Quality
- Using the Sustainable Livelihoods Framework
 	
Four Capitals:
- Social Capital
- Human Capital
- Physical Capital
- Financial Capital
	• Aboriginals in more urban ER tend to have greater adaptive capacity to manage the issues and opportunities offered by all four management approaches, compared to the more rural and remote regions.
	• Some rural and remote regions differ in their adaptive capacity because of past experiences in participating in mega-scale projects.
	• A recent study by Cooke *et.al*.[32] indicates that aboriginal communities in southern BC, southeastern Ontario and the Yukon have the highest well-being.
		• The risk of inaction is high. There is a direct need for investment in Aboriginal community services, infrastructure and institutions to enable effective and meaningful discussions with the NWMO and others.	• Cooke *et. al*, 2004, indicate that 92 aboriginal communities appear in the bottom 100 of Canadian communities in 2001, while only one First Nation appears in the top 100.
			• This study indicates that the Sustainable Livelihood capitals measured for aboriginal communities in the illustrative economic regions tend to score poorly in the rural and remote regions.
			• Lack of social, human, and physical capitals make it very difficult for Aboriginals to engage in effective and meaningful dialogue with the NWMO and to participate in the many economic benefits linked to the implementation of any of the management approaches.
			• Likewise, as the "boom & bust" cycle hits any of the regions, aboriginal communities will be affected like all others, in having to cope with a wide range of social and infrastructure issues. To an even greater extent than non-aboriginal people, Aboriginal people who are focused on the following attributes are unlikely to be able to engage fairly on discussions, dialogue and community preparation activities:
			  • Simply maintaining their livelihoods;
			  • Dealing with life stress;
			  • Caring for children and the elderly;
			  • Living on relatively low incomes;
			  • Living in sparsely populated areas where transportation and communication challenges are many;
			  • Few people with post-secondary education;
			  • Having few experienced and employed professionals who could assist in shaping discussions and required negotiations; and
			  • Having a variety of health challenges to deal with.
			• These and other issues need to be managed at the outset by investing in long-term community planning, infrastructure services, and institutional strengthening.

[32] Cooke, Beavon and McHardy, *Measuring the Well-Being of Aboriginal People: An application of the United Nations' Human Development Index to Registered Indians in Canada, 1981 – 2001*, 2004.

9.0 ANALYSIS OF ENVIRONMENTAL INTEGRITY

9.1 Context for the Analysis of Environmental Integrity

Objective: *The selected management approach needs to ensure that environmental integrity over the long-term is maintained. Concerns include the possibility of localized or widespread damage to the ecosystem or alteration of environmental characteristics resulting from chronic or unexpected release of radioactive or non-radioactive contaminants. Concerns also include stresses and damage associated with new infrastructure (such as roads and facilities) and operations (e.g., transportation)*[33].

9.2 Influencing Factors and Measures Used in the Analysis of Environmental Integrity

Similar to the analysis of the other three approaches described in the Technical Report (GAL–GLL, 2005), the following influencing factors and measures are used in the assessment of Adaptive Phased Management:

Influencing Factors used in Preliminary Comparative Assessment	Influencing Factors used in this Analysis	Measures used in this Analysis
Risk Scenario • Expected conditions (normal operation) • Off-normal scenarios	Type of Impacts of Construction and Operations Activities (normal conditions and accident conditions) • Physical disturbances • Radioactive releases • Conventional contaminant releases	Identification and qualitative analysis of the pathways between construction and operation activities and the environmental receptors
Likelihood of Impact to Resource • Expected conditions (normal operation) • Off-normal scenarios	Likelihood of pathway to receptor • Normal conditions • Accident conditions	Identification and qualitative analysis of the likely pathways by which stressors could act on the environmental receptors
Number/Sensitivity Elements of Ecosystem Potentially Impacted • Species • Watershed • Wetlands • Cultural/archaeological • Land use and extent • Aesthetics	Receptors or resources potentially affected • Natural environment • Human environment	• Ecozones • Forest regions • Presence of sensitive habitats • Presence of rare, endangered or threatened species/habitats

[33] Nuclear Waste Management Organization *Understanding the Choices – The Future Management of Canada's Used Nuclear Fuel*, September 2004, pg. 67.

Influencing Factors used in Preliminary Comparative Assessment	Influencing Factors used in this Analysis	Measures used in this Analysis
Significance of potential consequences to impacted resource	Significance of effect on impacted receptor	• Likelihood of occurrence of effect • Severity of effect • Ability to detect and/or monitor effect • Permanence of effect

9.3 Results of Environmental Integrity Analysis

Methods used in the analysis of Adaptive Phased Management are similar to those used in the Technical Report (GAL-GLL, 2005). However, this analysis assessed the environmental integrity of the Adaptive Phased Management Approach across the three phases of the project (refer to Section 2).

9.3.1 Define Features of the Environment

As part of the environmental integrity analysis, the ecozones were identified for each of the four illustrative ERs. The distribution of ecozones with respect to illustrative ERs was included in the Technical Report (GAL-GLL, 2005). The ecozones in which facilities could be located include the Boreal Shield, the Taiga Shield, and the Mixedwood Plains. As well, since transportation from the reactor sites to the a central site is a consideration of Adaptive Phased Management, the Prairies and Boreal Plains, and Atlantic Maritime ecozones are also included in the analysis, as transportation routes may pass through these ecozones.

Since forest type is often a major factor in determining which animal and plant species are present, the forest regions for each illustrative ER were also identified [see Figure 9.4-2 of the Technical Report (GAL-GLL, 2005)].

Table 9.3-1 summarizes the ecozones and forest regions applicable to each illustrative ER for Adaptive Phased Management.

TABLE 9.3-1:
ECOZONES AND FOREST REGIONS BY
ILLUSTRATIVE ECONOMIC REGION

Economic Region	Ecozone	Forest Region
Adaptive Phased Management		
ER-2	Boreal Plains	• Boreal Forest • Boreal Forest and Grass
	Prairies	• Grasslands
	Boreal Shield	• Boreal Forest
	Taiga Shield	• Boreal Forest and Barren
ER-4	Boreal Plains	• Boreal Forest • Boreal Forest and Grass
ER-5	Mixedwood Plains	• Great Lakes-St. Lawrence
ER-9	Boreal Shield Taiga Shield	• Boreal Forest • Boreal Barren • Boreal Forest and Grass

9.3.2 Characterize Features of Existing Environment

The features of each of the ecozones were described paying particular attention to those species or habitats considered sensitive. A brief overview of the key environmental features of each of these ecozones is provided in Section 9.4.2 of the Technical Report (GAL-GLL, 2005).

In summary, all ecozones within the illustrative ERs have unique features and characteristics in terms of the physical and biophysical environments and are sensitive to environmental impacts. Environmental features and characteristics relevant to the scale of a facility will vary across ecozones and thus across ERs. As this assessment is not a siting study, the actual features at the facility level for any of the management approaches cannot be exactly determined. It may be possible to site a management facility at a location within any of the ecozones noted in Table 9.3-1 without causing significant adverse environmental effects.

9.3.3 Identify and Characterize the Project Works and Activities

The detailed environmental integrity analysis considered an extensive number of project works and activities for the Adaptive Phased Management Approach. Table 9.3-2 summarizes the activities considered under normal conditions and the expected type of impacts resulting from each activity. Under normal conditions, it is assumed that all systems perform as designed and there are no releases of radionuclides or conventional contaminants.

TABLE 9.3-2:
PROJECT WORKS AND ACTIVITIES AND
POTENTIAL TYPE OF IMPACTS – NORMAL CONDITIONS

	Applicable to Management Approach	Type of Impact		
Project Work or Activity	**Adaptive Phased Management**	**Physical Impact**	**Radiological Impact**	**Conventional Contaminant Impact**
Site Preparation and Containment Construction	•	•		
Access Construction	•	•		
Re-packaging for Shipment	•			
Transport to Storage Site	•			
Monitoring Activities in Near Term	•			
Passive Storage in Near Term	•			
Backfill and Storage in Long Term	•	•		
Active Storage in Long Term				
Building Refurbishments and Repackaging	•	•		

A number of different off-normal scenarios were also considered in the analysis. Five representative accident scenarios (some of them bounding accidents) were considered. They are as follows:

- **Minor Upset on Site**: Leak in the containers during passive storage at the management facility (with no damage to the ventilation or other containment systems);
- **Major Upset on Site (bounding)**: DSC drop during on-site transfer or fuel handling in the process building of the management facility (i.e., 100% failure of all fuel bundles and liberation of entire free inventory of tritium and Kr^{85} immediately into the environment) (applicable at the beginning of Phase 2 and Phase 3);
- **Major Upset on Site (bounding)**: Failure in the shaft and hoisting facilities in the below-ground management facility with ventilation failure (i.e., airborne particulates will bypass the High Efficiency Particulate Air filters) (applicable to Phase 3);
- **Minor Upset in Transit**: A road or rail accident during transport (on or off site) causing the loss of a container with the integrity of the container not being compromised (i.e., no loss of contaminant, majority of effects associated with recovery of the container) (applicable to Phase 2); and

- **Major Upset in Transit (bounding)**: A road or rail accident during transport (on or off site) causing the loss of a container and the integrity of the container being compromised (i.e., loss of contaminant, release of contents to air and water) (applicable to Phase 2).

Table 9.3-3 summarizes the potential types of impacts associated with each of the off-normal scenarios.

TABLE 9.3-3:
OFF-NORMAL SCENARIOS AND POTENTIAL TYPE OF IMPACTS

Off-Normal Scenario	Applicable to Management Approach	Type of Impact		
	Adaptive Phased Management	Physical Impact	Radiological Impact	Conventional Contaminant Impact
Minor Upset Onsite (leak in container, no damage to ventilation system)	Yes			
Major Upset Onsite (DSC drop during onsite transfer)	Yes		●	●
Major Upset Onsite (failure in shaft and hoisting facility)	Yes		●	●
Minor Upset in Transit (integrity of container not compromised)	Yes	●		
Major Upset in Transit (loss of container integrity)	Yes	●	●	●

9.3.4 Identify Pathways Between the Project and the Environment

The same pathways were identified for the Adaptive Phased Management Approach as were identified in the Technical Report (GAL-GLL, 2005).

9.3.5 Identify Receptors Present if Defined Pathways

Potential receptors for stressors were defined for each of the normal and off-normal activities determined to have a realistic pathway between Adaptive Phased Management and the environment. Only where there is a pathway is there a potential for a receptor to be exposed. Table 9.3-4 summarizes the potential receptors identified.

TABLE 9.3-4:
POTENTIAL RECEPTORS – NORMAL AND OFF-NORMAL SCENARIOS

Project Work or Activity	Receptor(s) Potentially Affected
Normal Scenarios	
Site Preparation and Containment Construction	Vegetation, terrestrial biota, aquatic biota (either directly or by loss of habitat)
Access Construction	Vegetation, terrestrial biota, aquatic biota (either directly or by loss of habitat)
Backfill and Storage in Long Term	Terrestrial biota, aquatic biota (either directly or by loss of habitat)
Building Refurbishments and Repackaging (in near term)	Vegetation, terrestrial biota, aquatic biota (either directly or by loss of habitat)
Off-Normal Scenarios	
Major Upset Onsite (DSC drop during onsite transfer)	All habitats and biota (through release of container contents to air and/or water)
Major Upset Onsite (failure in shaft and hoisting facility)	Terrestrial biota, including humans, aquatic biota, contamination of vegetation (through airborne contamination)
Minor Upset in Transit (integrity of container not compromised)	Vegetation, terrestrial biota, aquatic biota (through direct impact of containers in aquatic environment, or by impact of machinery in recovery process)
Major Upset in Transit (loss of container integrity)	Vegetation, terrestrial biota, aquatic biota (through direct impact of containers in aquatic environment, impact of machinery in recovery process or through radioactive contamination)

9.3.6 Identify and Assess Potential Effects

A detailed assessment of potential effects of Adaptive Phased Management was carried out and considered the activities described in Section 9.3.3 together with the major features of each ecozone as described in Section 9.3.2. The assessment was carried out using the methodology as described in the Technical Report (GAL-GLL, 2005).

The assessment considered both normal and off-normal scenarios. Table 9.3-5 summarizes the potential effects, by activity, of Adaptive Phased Management under normal conditions. The description of the significance of the effects is provided in Section 9.3.7.

TABLE 9.3-5:
SUMMARY OF POTENTIAL EFFECTS UNDER NORMAL CONDITIONS

Approach	Activity	Ecozone	Likelihood of Occurrence	Ability to Monitor/Detect	Severity of Effect	Permanence
Adaptive Phased Management	All Activities	• Boreal Shield (ER-2, ER-4) • Mixedwood Plains (ER-5) • Taiga Shield (ER-9)	Low for all activities under normal conditions	Good until Closure Poor after Closure (Phase 3)	Low, with the exception of habitat loss due to surficial facility construction	Low, with the exception of permanent habitat loss due to surficial facility construction

Following closure of the deep isolation facility, monitoring will continue, but at a reduced level.

Table 9.3-6 summarizes the potential effects, by scenario and time period, of Adaptive Phased Management under off-normal accident conditions. While all environments are sensitive to the effects of stressors, some environments are inherently more sensitive. These are often those that possess unique features, or are already under stress from other factors that have resulted in a loss of stabilizing factors that provide resiliency. In these areas the effects of accidents could result in greater ecological damage than in areas with greater resiliency or fewer unique features.

TABLE 9.3-6:
SUMMARY OF POTENTIAL EFFECTS UNDER ACCIDENT (OFF-NORMAL) CONDITIONS – ADAPTIVE PHASED MANAGEMENT

Accident Scenario	Ecozone (Economic Region)	Likelihood of Occurrence	Ability to Monitor/ Detect	Severity of Effect	Permanence
Minor upset on site (leak) (yrs. 30-89)	• Boreal Shield (ER-2, ER-4) • Mixedwood Plains (ER-5) • Taiga Shield (ER-9)	Low	Good	Low	Low
Minor upset on site (leak) (yrs. 90-300)	• Boreal Shield (ER-2, ER-4) • Mixedwood Plains (ER-5) • Taiga Shield (ER-9)	Low	Moderate	Low	Low
Minor upset on site (leak) (yrs. 301+)	• Boreal Shield (ER-2, ER-4) • Mixedwood Plains (ER-5) • Taiga Shield (ER-9)	Low	Poor	High	High
Major upset on site (spill)	• Boreal Shield (ER-2, ER-4)	Very Low	Good	High	High
	• Mixedwood Plains (ER-5) • Taiga Shield (ER-9)	Very Low	Good	Severe	High
Major upset	• Boreal Shield (ER-2, ER-4	Very Low	Good	High	High

Accident Scenario	Ecozone (Economic Region)	Likelihood of Occurrence	Ability to Monitor/ Detect	Severity of Effect	Permanence
on site (shaft failure)	• Mixedwood Plains (ER-5) • Taiga Shield (ER-9)	Very Low	Good	Severe	High
Minor upset in transit	• Boreal Shield (ER-2, ER-4, ER-5) • Prairies (ER-2) • Boreal Plains (ER-2)	Low	Moderate	Low	Low
	• Mixedwood Plains (ER-4, ER-5)	Low	Good	Moderate	Low
	• Taiga Shield (ER-5, ER-9)	Low	Moderate	Moderate	Low
	• Atlantic Maritime (all ER's)	Low	Good	Low	Low
Major upset in transit	• Boreal Shield (ER-2, ER-4) • Taiga Shield (ER-9) • Boreal Plains (ER-2) • Prairies (ER-2)	Very Low	Moderate	High	High
	• Mixedwood Plains (ER-4, ER-5) • Atlantic Maritime (all ER's)	Very Low	Good	Severe	High

9.3.7 Assess the Significance of Adverse Environmental Effects

The analysis of effects indicated that Adaptive Phased Management is safe if constructed and operated as designed (i.e., any adverse environmental effects are not expected to be significant).

Any anticipated minor adverse environmental effects under normal conditions would be limited to physical disruption of the site, with the associated loss of vegetation and habitat, and effects of some conventional contaminants, such as fuels and lubricants, during construction and refurbishment activities. As a result, this management approach can be constructed and operated under normal conditions in any illustrative ER without causing unacceptable risks to the environment.

The analysis indicates that under off-normal (accident) scenarios, particularly those that involve release of contaminants, effects could be more severe in those areas which are more susceptible to a local impact. These are generally the ecozones which have had extensive impacts due to historical anthropogenic activities, and, therefore, have a larger number of sensitive habitats and rare, threatened and endangered species. Releases to water, present special concerns for both the environment and humans.

As noted, the highest risk areas, under accident scenarios, are those adjacent to large bodies of water, since impacts on these water resources could be far-ranging and potentially have international consequences. These areas include the Mixedwood Plains ecozone (which is adjacent the Great Lakes) and the Atlantic Maritime ecozone (adjacent to the Atlantic Ocean). In addition, the Mixedwood Plains and the Prairies both contain unique habitats that, in some cases, are found nowhere else, and thus would be particularly more susceptible to adverse effects.

The lowest risk areas are those ecozones that are less susceptible to a local impact. Generally, these are the ecozones which have not had extensive human impacts and still have large undisturbed tracts of land. These areas are characterized by large tracts of similar habitat and relatively sparse development, and a therefore greater degree of resiliency. Additionally, water bodies in these regions tend to be smaller with less potential for far-reaching effects on water resources. However, the presence of large rivers will necessitate the need for careful consideration during final siting to minimize the potential for adverse effects.

The transportation routes for the Adaptive Phased Management Approach have the potential to traverse multiple ecozones, depending on the ultimate location of the facilities.

9.3.8 Qualitative Description of Other Factors

Analysis related to Adaptive Phased Management is different for one of the three influencing factors (i.e., 'off-normal scenarios') that were described in Section 9.4.8 in the Technical Report (GAL-GLL, 2005):

- Climate Change – Includes climatological events such as glaciation (i.e., an ice age). Surficial storage facilities would not be capable of withstanding a glaciation event; however, under Adaptive Phased Management, the wastes are stored deep underground, and the integrity of these underground facilities is such that they would be capable of withstanding the effects of a glaciation event.

9.4 Summary of Environmental Integrity Analysis

The same measures related to environmental integrity were analyzed in detail for Adaptive Phased Management in this report as were analyzed previously for the other three approaches in the Technical Report (GAL-GLL, 2005). This analysis included consideration of risk scenario, receptors or resources potentially affected, and significance of effects on the impacted receptor.

A summary of the environmental integrity analysis for Adaptive Phased Management in terms of the benefits, risks, and costs is discussed below. Following that, a rollup comparison of all four management approaches is presented in Table 9.4-1.

Benefits

This approach can be constructed and operated without causing significant adverse effects on the environment in the near and long term. This is achieved by implementing standard mitigation measures and best management practices. The likelihood of an off-normal event occurring for each of the approaches is low to very low. This is independent of ER.

The Adaptive Phased Management option allows for monitoring of the site after decommissioning of the facilities under the notion/assumption that new technologies for monitoring have the potential to be developed by future generations.

Risks

A distinguishing factor between the approaches is the ability to monitor their environmental performance over the long term. Following decommissioning and closure of the deep isolation facility of Adaptive Phased Management, on-going monitoring of the decommissioned and closed facility has been allowed for under the assumption that new technologies for monitoring have the potential to be developed by future generations. However, the likelihood of an adverse effect occurring is low because of the physical and geological barriers in the underground facility.

The transportation routes for Adaptive Phased Management would likely traverse multiple ecozones. Risks associated with transportation would be lowest for illustrative ERs that are located closest to the current reactor sites.

The analysis of off-normal scenarios, particularly those that involve release of contaminants, indicates that effects could be more severe in those ERs with a greater number of sensitive habitats and species. These ecozones may also have been previously impacted by historical activities and therefore be more susceptible to further disturbance. The effects of off-normal scenarios will be most severe in those locations adjacent to large continuous bodies of water, as the impacts on the water resources could be far ranging and have international consequences.

All ecozones are sensitive to environmental impacts. Environmental features and characteristics at the facility level will vary across ecozones and thus across ERs. As noted above, this assessment is not a siting study using site-specific information and accordingly the significance of potential adverse effects at the facility level for any of the management approaches cannot be exactly determined within the scope of this assessment.

Costs

Some of the costs for environmental integrity are accounted for in the economic costs through facility designs and monitoring programs. However, should societal values and/or environmental risks change with time, the degree to which Canadians understand what effects the environment might also change. For example, society today places a higher value on environmental integrity than was the case 25 years ago. Therefore, mitigation measures and compensation, if required, may result in additional future costs not included in the current cost estimates.

TABLE 9.4-1: SUMMARY OF ENVIRONMENTAL INTEGRITY ANALYSIS – A COMPARISON OF MANAGEMENT APPROACHES: BENEFITS, RISKS AND COSTS

Measure or Indicator	Benefits	Risks	Costs
Sensitivity of Receptors Potentially Affected	• There are no benefits associated with this measure.	• All ecozones are sensitive to environmental impacts. Environmental features and characteristics at the facility level will vary across ecozones and thus across economic regions. This assessment is not a siting study using site-specific information and accordingly the significance of potential adverse effects at the facility level for any of the management approaches cannot be exactly determined within the scope of this assessment. • For normal scenarios the risk of adverse environmental effect for all approaches can be avoided or minimized through the application of best management practices. • For off-normal scenarios, the risk of adverse environment effects could be greater in those economic regions with a greater number of sensitive species and habitats. These ecozones may also have been previously impacted by historical activities and may be more susceptible to further disturbance.	• There are no costs associated with this measure.

Measure or Indicator	Benefits	Risks	Costs
Significance of the Effect on the Environment	• Under normal conditions, all four management approaches can be constructed and operated without causing significant averse effects on the environment in the near and long term. This is achieved by implementing standard mitigation measures and best management practices. • There is no requirement for off-site transportation of used nuclear fuel for Storage at Nuclear Reactor Sites; therefore, there are no associated risks to the environment due to a transportation accident, although the likelihood of occurrence of a transport accident is low to very low. • Deep Geological Disposal in the Canadian Shield and Adaptive Phased Management offer a benefit over the other two approaches with respect to withstanding effects of significant environmental change in the long term. The nature of the facility is such that it would not be susceptible to the effects of a glacial event. Facilities constructed at or near the surface are less likely to withstand such an event.	• Following closure of the Deep Geological Disposal in the Canadian Shield or Adaptive Phased Management facility in years 154 and 325, respectively, monitoring for potential effects is difficult because of the nature of a facility; however, the likelihood of an adverse effect occurring is low because of the physical and geological barriers in a underground facility. • Adverse effects of off-normal scenarios that may be most severe are in those locations adjacent to large continuous bodies of water, as the impacts on the water resources could be far ranging and could have international consequences. Storage at Nuclear Reactor Sites has the largest number of sites adjacent to large international water bodies. Additionally, Storage at Nuclear Reactor Sites will have seven separate facilities and therefore more potential interactions with the environment. • All approaches other than Storage at Nuclear Reactor Sites require off-site transportation with the associated risks. However, best environmental management practices will be used to ensure these risks are low. The transportation routes for Centralized Storage (above or below ground), Deep Geological Disposal in the Canadian Shield and Adaptive Phased Management would likely traverse multiple ecozones. In addition, risks associated with transportation would be lowest for illustrative economic regions that are located closest to the current reactor sites.	• Some costs for environmental integrity are accounted for in the economic costs of the management approaches through facility designs and monitoring programs. However, should societal values and/or environmental risks change with time, the degree to which Canadians understand what effects the environment might change. For example, society today places a higher value on environmental integrity than 25 years ago. Therefore, mitigation measures and compensation, if required, may result in additional future costs not included in the current cost estimates.

10.0 ANALYSIS OF ADAPTABILITY

10.1 Context for the Analysis of Adaptability

Objective: *If something is adaptable, it means that it can modified to fit new or unforeseen circumstances. Although this is an attractive feature for a selected approach, the objective of adaptability as defined here is broader. Adaptability is regarded as a fundamental objective for selecting an approach for the long-term management of nuclear fuel, not just a means to help ensure that other objectives identified in the hierarchy can be achieved* [34].

The reason that adaptability was identified as a fundamental objective derives from the very long time frame over which the approach must operate. Generations in the distant future may see things differently than we do today. They may have different objectives than those represented in Figure 4-4 (ref: Understanding the Choices) or, at least, they may place very different weights on those objectives. It is desirable, therefore, that we facilitate the ability of future generations to pursue and attain their own objectives, whatever they may be. Thus, adaptability reflects our desire for an approach that provides flexibility to future generations to change decisions. It also includes our desire not to place burdens or obligations on future generations that will constrain them. Furthermore, adaptability, as defined here, includes consideration of degrees to which the selected approach is able to function satisfactorily in the event of unforeseen "surprises"[35].

10.2 Influencing Factors and Measures Used in the Analysis of Adaptability

Similar to the analysis of the other three approaches as described in the Technical Report (GAL-GLL, 2005), the following influencing factors and measures were considered in the assessment of Adaptive Phased Management:

Influencing Factors used in Preliminary Comparative Assessment	Influencing Factors used in this Analysis	Measures used in this Analysis
Availability of Necessary Capacity, Mechanisms And Resources For Long Term	Availability of Necessary Capacity, Mechanisms And Resources For Long Term	• Financial viability (and surety) – cost requirements over time • Possible safety and environmental concerns and the institutional and operational framework(s) required to ensure long-term viability and monitoring
Adequacy of Institutions and Governance	Adequacy of Institutions and Governance	• Consideration of adequacy of institutions and governance models

[34] Nuclear Waste Management Organization, *Understanding the Choices – The Future Management of Canada's Used Nuclear Fuel*, September 2004, page 71.
[35] *ibid*, page 71.

Influencing Factors used in Preliminary Comparative Assessment	Influencing Factors used in this Analysis	Measures used in this Analysis
Ability/Need to Take Corrective Actions That Address Surprises	Ability/Need to Take Corrective Actions That Address Surprises	• Approach flexibility/irretrievability • Susceptibility to "surprises" • Planning for adverse effects • Monitoring and implementation of corrective measures. • Ability to monitor performance • Opportunities for monitoring and periodic reassessment • Speed of adjustment • Repairability/reversibility
Accountability	Accountability	• Opportunity for public to influence decision-making

10.3 Summary of Adaptability Analysis

Adaptability as considered in this assessment relates to the ability of future generations to modify or change aspects of any management approach over time in response to changing societal values and/or technology. The comparative assessment of the management approaches was based on the study team's judgement of how each of the approaches relate to the influences identified by the Assessment Team. No additional criteria or impact measures for the adaptability objective were developed.

It is recognized that "adaptability" is comprised of many considerations and elements as identified by the NWMO Assessment Team. The influencing measures that the current study team focused on include the following:

- Availability Of Necessary Capacity, Mechanisms And Resources For Long Term
- Adequacy of Institutions and Governance
- Ability/Need to Take Corrective Actions That Address Surprises
- Accountability

Each of the above four measures are consistent with those considered in other studies of this nature, but more important, they are the key impact measures identified by the Assessment Team. The location of any management approach is not a significant factor in the assessment of adaptability.

A summary of the key issues relating to the adaptability analysis for Adaptive Phased Management in terms of the benefits, risks and costs is discussed below. Following that, a rollup comparison of all four management approaches is presented in Table 10.3-1.

Benefits

Being able to offer a “complete” solution in the near term is considered valuable from a number of perspectives. This approach has used nuclear fuel 'in place' in a deep isolation facility by year 89, with the added feature of being accessible (i.e., open) for testing and monitoring purposes up to year 325. Keeping the deep isolation facility open for a significant period of time allows for “proof of concept” as well as opportunity to incorporate new and existing technologies.

Risks

Once decommissioned and closed, the facility is not easily accessible, nor can future generations utilize new technologies or methods should they prove superior to current ones.

The ability to monitor and take corrective actions with this approach is reduced and delayed, respectively, once the facility is decommissioned and closed by year 325.

Costs

Should used nuclear fuel need to be retrieved from a decommissioned and closed isolation facility, the cost to do so has not been factored into the cost estimates presented in Section 7.

TABLE 10.3-1: SUMMARY OF ADAPTABILITY ANALYSIS - A COMPARISON OF MANAGEMENT APPROACHES: BENEFITS, RISKS AND COSTS

Measure or Indicator	Benefits	Risks	Costs
Availability of Necessary Capacity, Mechanisms And Resources For Long Term	• Being able to offer an "immediate" solution in the near term is a benefit, since it does not handicap future generations in terms of cyclical or significant costs to manage. Deep Geological Disposal in the Canadian Shield is 'in place' by year 59, with decommissioning and closure by year 154, and Adaptive Phased Management, is also in a centralized storage facility by that time, but is not finally emplaced until year 89, with decommissioning and closure by year 325 following an extended monitoring period. Because of this relatively short-term management approach for both, the need for adaptability in relation to financial surety is minimal in comparison to Centralized Storage (above or below ground) or Storage at Nuclear Reactor Sites, which both incur costs for thousands of years. • It is understood that all the necessary technologies, processes, financial means and other resources are currently available for Deep Geological Disposal in the Canadian Shield, and Adaptive Phased Management. This is also true for the other two storage approaches, with the exception of surety of financial resources (see discussion in Section 7). • All four management approaches will require long-term monitoring as it relates to safety and environmental concerns. The institutions and management responsibilities for used nuclear fuel for all these approaches will require some form of oversight, which cannot be guaranteed in the long term. However, Deep Geological Disposal in the Canadian Shield can remain in place with no planned intervention. The same is true for Adaptive Phased Management, after year 325, which in the overall scheme of managing used nuclear fuel is a short time period. However, Centralized Storage (above or below ground) and Storage at Nuclear Reactor Sites both require active management interventions on a regular basis for thousands of years to come. This constitutes a benefit for Deep Geological Disposal in the Canadian Shield on one hand, yet this also poses a risk that it is very difficult to monitor environmental effects for this approach and the corrective actions. Adaptive Phased Management offers twin benefits of developing a long term solution in a relatively short time frame (325 years), yet enables easy access and active monitoring capability up to that point. This offers added time for "proof-of-concept" as well as opportunity to incorporate new and evolving technologies. • There is no clear location benefit for any of the management approaches as it relates to adaptability.	• The risk consideration that most impacts adaptability relates to changing science, technology, and social values over time. As these change, one might be required to make changes to any of the four management approaches. Consider for example how science and technology has changed over the past 50 years in relation to municipal waste disposal. Specifically, municipalities dumped all forms of waste into "dumps" with less regard for how groundwater might be affected over the long-term. This situation arose because there was limited science available to indicate the effects and consequences that now have to be dealt with, such as leachate seepage into groundwater and its attendant cost of remediation. • It is not possible to predict how scientific knowledge or technology will change over time, other than it is reasonable to expect that it will change. At the same time, social dynamics and institutions that influence the mechanisms and processes for managing used nuclear fuel are also likely to change. Taken together, these changes will affect how society values risk and the trade-offs used to evaluate the management approaches. Over the long term, it is not possible to guarantee that the necessary safety and environmental concerns will be monitored, nor can one guarantee if the institutional and operational framework(s) required to ensure long-term monitoring and management will be in place. Even if these are in place, it is possible that any one of the four management approaches might require retrieving and/or mitigation measures to prevent or reverse possible adverse effects. • In the latter case, the cost of retrieval from a decommissioned and closed Deep Geological Disposal in the Canadian Shield facility , or a decommissioned and closed Adaptive Phased Management facility will likely cost less than the incremental cost to manage the other two storage approaches over the very long term. This statement is based on a cash flow analysis and does not take into account the present value of these added cost requirements.	• Retrieval of nuclear fuel from a decommissioned and closed Deep Geological Disposal in the Canadian Shield facility or a decommissioned and closed Adaptive Phased Management facility is more difficult, costlier and more time consuming than for Centralized Storage (above or below ground) or Storage at Nuclear Reactor Sites facilities. These costs have not been included in the preliminary and conceptual design cost estimates. • Adaptive Phased Management offers an extended period of storage compared to Deep Geological Disposal in the Canadian Shield that can be used to "prove" the technology and react to new technological developments should they arise. This extended storage and monitoring period (approximately 210 years) reduces the potential requirement for and the cost of retrieval from a decommissioned and closed long-term isolation facility. • Costs related to reversing adverse health or environmental effects vary depending on the specific situation. However, since it is more difficult to monitor environmental effects for the Deep Geological Disposal in the Canadian Shield or Adaptive Phased Management, after closure, it is reasonable to assume that it will take longer to discover adverse effects compared to Centralized Storage (above or below ground) or Storage at Nuclear Reactor Sites, which remain open for the very long-term. As a result, there is greater risk and higher potential remediation cost, with Deep Geological Disposal in the Canadian Shield or eventually Adaptive Phased Management, even though the probability of adverse effects after closure are considered to be very low for these two approaches.

Measure or Indicator	Benefits	Risks	Costs
Adequacy of Institutions and Governance	• Over the long term, it is likely that institutions and governance will change if recent history is any indicator. Only the Deep Geological Disposal in the Canadian Shield approach minimizes the need for institutions and governance because actions are not required after year 154. This assumes that predicted "normal" operating conditions prevail and that there is no need for interventions (i.e., used nuclear fuel retrieval or mitigation of adverse effects). Even Adaptive Phased Management is less dependent on institutions and governance in the long term because actions are not required after year 325 other than long-term monitoring. Centralized Storage (above or below ground) and Storage at Nuclear Reactor Sites require on-going active management and financial resources over the very long term with the associated institution controls and governance.	• In comparison, Centralized Storage (above or below ground) and Storage at Nuclear Reactor Sites require numerous periodic future interventions that will be influenced by future applicable governing laws, market forces/incentives, cultural/social values and norms, and the synthesis of continual learning. Although a benefit on one hand, (e.g., one can leverage the best science of the day to repackage used nuclear fuel), it also poses some risk. The risk is that the necessary support institutions and governance frameworks we now rely on will not be there in the very long term.	• The adequacy of institutions and governance in the long term is a critical consideration. There are no other similarities found in history that one can learn from. With Centralized Storage and Storage at Nuclear Reactor Sites, the cost to future generations in ensuring the financial and institutional stability of overseeing agencies will be significant. • However, it is possible that new technologies may arise that are less costly and more effective in managing used nuclear fuel, thus lessening the risk and costs to future generations.
Ability/Need to Take Corrective Actions That Address Surprises	• As discussed in previous sections, Deep Geological Disposal in the Canadian Shield is less "susceptible" to security breeches and, if sited according to appropriate conditions, it is also environmentally safe based on current scientific knowledge. This, as the NWMO Assessment Team states, reduces the need for flexibility in relation to long-term monitoring and contingency planning. However, like the municipal waste management example cited under risks, "we do not know what we do not know", and we may think that we are more secure in theory than in fact. • The Adaptive Phased Management Approach, offers the benefit of an extended storage period that enables continued research and development and monitoring activities to "prove" the concept and design parameters to the satisfaction of multiple generations. If satisfied, future generations can decide to proceed with long-term isolation of the used nuclear fuel or implement an alternative approach at that time.	• The ability to monitor and take corrective actions when required is easier and less costly for Centralized Storage (above or below ground) and Storage at Nuclear Reactor Sites, compared to Deep Geological Disposal in the Canadian Shield. This reduces the environmental and health risks for these approaches. • The risk of Adaptive Phased Management, is lessened considerably for the next 300 or so years, relative to Deep Geological Disposal in the Canadian Shield.	
Accountability	• A critical success factor in the decision-making process for selecting an appropriate used nuclear fuel management approach is providing opportunity for public stakeholders to influence the process. This element of accountability has been discussed in the Community Well-Being Objective. It is important to add, however, that public consultation does not begin and end in selecting a preferable management approach. Rather, an open and transparent process should continue over the long term in relation to monitoring and new knowledge about how best to deal with used nuclear fuel. In this regard, Adaptive Phased Management offers an advantage over Deep Geological Disposal in the Canadian Shield in that it allows for both current and near current generations to participate in the selection and design of a long-term approach before it is fully implemented.	• Implementation planning and corrective measures can only be accountable if the affected stakeholders have the necessary support tools, training and infrastructure to participate in the process in a meaningful and constructive way (see Section 8).	

11.0 ANALYSIS OF FAIRNESS

11.1 Context for the Analysis of Fairness

***Objective**: The selected approach, among other things, should produce a fair sharing of costs, benefits, risks, and responsibilities that is regarded as being fair as possible now and in the future*[36].

***General principle for guiding the assessment of fairness**: The management system and technologies used should ensure that the persons and communities likely to be most directly affected by any activities or consequences of the management of the used fuel have opportunity to participate in decisions in advance of the establishment of the used nuclear fuel management facility; that characteristics of the distribution of short-term and long-term health, environment, or economic costs and obligations are understood and accepted at the time of decision; and that adequate attention is given, as far as possible by the current generation, to intra-generational, inter-generational and inter-species aspects of the system selected*[37].

11.2 Influencing Factors and Measures Used in the Analysis of Fairness

Similar to the analysis of the other three approaches described in the Technical Report (GAL-GLL, 2005), the following influencing factors and measures are used in the assessment of Adaptive Phased Management:

Influencing Factors used in Preliminary Comparative Assessment	Influencing Factors used in this Analysis	Measures used in this Analysis
Intergenerational Fairness	Intergenerational Fairness	• Intergenerational distribution of costs – should future generations have to solve this generation's problem? • Respect for interests of future generations • Current generation acceptance of responsibility for creating and solving used nuclear fuel issue • Taking responsibility versus preserving flexibility for future
Interspecies Distributional Fairness	Interspecies Distributional Fairness	• Human and non-human cost and benefits over time • Respect for life and biosphere
Distributional Fairness for Humans	Distributional Fairness	• Decision Flexibility • Adherence to polluter pays principle • Transportation risks and other considerations • Distributional fairness of impacts on communities

[36] Nuclear Waste Management Organization, *Understanding the Choices – The Future Management of Canada's Used Nuclear Fuel*, September 2004, page 56
[37] *ibid*, page 56.

Influencing Factors used in Preliminary Comparative Assessment	Influencing Factors used in this Analysis	Measures used in this Analysis
Participation Engagement & Participatory Decision Making	Opportunity to Influence Decision Outcomes	• Governance model(s) • Status of aboriginal land claims • Capacity for Public Engagement • State of sustainable livelihoods capitals in each of the economic regions • Identification of appropriate investments and mitigation measures in the five capitals

11.3 Summary of Fairness Analysis – A Comparison of Management Approaches

Fairness is about social equity. It relates to how various stakeholders participate in the management decision-making process for used nuclear fuel now and in the future, to ensure that social values are factored into the design, construction, and operational phases. The comparative assessment of fairness was based on the study team's judgement of how each of the approaches relate to the fairness influences identified by the NWMO Assessment Team. No additional criteria or impact measures for this objective were developed.

It was recognized that there are many influencing factors and measures for "fairness" as identified by the NWMO Assessment Team. The following four measures were selected for more detailed qualitative assessment:

- Intergenerational Fairness
- Interspecies Distributional Fairness
- Distributional Fairness
- Opportunity to Influence Decision Outcomes & Engagement in Decision Making

Each of the above four measures are consistent with those considered in other studies of this nature, but more important, they are the four key impact measures identified by the NWMO Assessment Team. The location of any of the management approaches does have some impact on the assessment of fairness.

A summary of the key issues relating to the fairness analysis for the Adaptive Phased Management Approach in terms of the benefits, risks and costs is discussed below. Following that a rollup comparison of all four management approaches is presented in Table 11.3-1.

Benefits

This management approach limits actions and associated financial liabilities to "near-current" generations. This is beneficial if one adheres to the "polluter-pays" principle.

Risks

There are no "fail- safe" solutions to long-term management of used nuclear fuel. However, the Adaptive Phased Management Approach has a high degree of inherent security once used nuclear fuel has been transported to a central site. Yet this approach reduces the ability of future generations to manage their own risks in terms of adopting new technologies or easily monitoring for potential adverse environmental effects.

The location of an Adaptive Phased Management site is important. If located in a region which contains higher population densities and/or sensitive ecozones, then the risks to people and the environment are higher.

Costs

The cost of an adverse impact is highly unpredictable at this point in time, specifically when this analysis has not made reference to any particular site or location. Having said this, it is reasonable to conclude that the social, human, and environmental cost of an adverse impact will be high and may impact multiple generations. Only a portion of these costs have been accounted for in the cost estimates presented in this report.

TABLE 11.3-1: SUMMARY OF FAIRNESS ANALYSIS - A COMPARISON OF MANAGEMENT APPROACHES: BENEFITS, RISKS AND COSTS

Measure or Indicator	Benefits	Risks	Costs
Intergenerational Fairness • Intergenerational distribution of costs • Respect for interests of future generations • Current generation acceptance of responsibility • Taking responsibility versus preserving flexibility for future	• One key benefit relates to the distribution of financial costs between the current and future generations resulting from any of the four management approaches. It is assumed that any management approach that limits the majority of actions, solutions and associated financial costs to the near term is more preferable because it limits procedural and financial burdens to the generation that benefited from the electricity derived from the nuclear fuel and does not put a significant financial burden on future generations who will not benefit. In doing so, it shows respect for the interests of future generations from a financial perspective and it adheres more closely to the "polluter-pays" principle. Both Deep Geological Disposal in the Canadian Shield and Adaptive Phased Management incur the majority of their respective costs in the near term, thus limiting financial liabilities and the financial surety for the most part to the next few generation(s), assuming that the facility operates as designed. • Both Centralized Storage and Storage at Nuclear Reactor Sites require future generations to more actively manage and finance the ongoing activities for thousands of years. However, these two management approaches offer greater flexibility to future generations in terms of making their own decision about how best to manage used nuclear fuel and to monitor human and environmental effects more effectively. It is important to note that both Deep Geological Disposal in the Canadian Shield and Adaptive Phased Management are planned to remain open or accessible for a period of about 100 years after the used nuclear fuel is finally in place for Deep Geological Disposal in the Canadian Shield and about 200 years for Adaptive Phased Management. This means that active and effective monitoring will be conducted over these time periods and should issues arise, corrective actions can be implemented, including retrieval and re-deployment. • The costs of both Deep Geological Disposal in the Canadian Shield and Adaptive Phased Management have a higher degree of certainty and confidence that the amount of financial resources required for implementation compared with Storage at Nuclear Reactor Sites and Centralized Storage, which require costs over the long term. • Selection of Deep Geological Disposal in the Canadian Shield or Adaptive Phased Management offers a variety of other benefits related to fairness, including institutional stability – i.e., it is likely that the institutions and processes required for the completion of Deep Geological Disposal in the Canadian Shield or Adaptive Phased Management are sustainable in the near term, whereas institutional stability in the long-term is likely to change and thus Storage at Nuclear Reactor Sites and Centralized Storage (above or below ground) could be at some added risk. • Adaptive Phased Management offers an added benefit in that the extended storage period of some 200 years enables extensive monitoring and proof of concept prior to the final placement of used nuclear fuel.	• Deep Geological Disposal in the Canadian Shield and Adaptive Phased Management reduce the ability of future generations to manage their own risks by making it difficult for them to monitor the facility and take corrective measures, if required, compared to Centralized Storage and Storage at Nuclear Reactor Sites. This means that Deep Geological Disposal in the Canadian Shield and Adaptive Phased Management both shift some of the risk from the current generation to future generations, in part because the multiple barriers might fail in the future and there is insufficient monitoring capability to measure when this might happen and how extensive the effect might be. Having said that, in the event that it is required, the cost of retrieval from a decommissioned and closed Deep Geological Disposal in the Canadian Shield or an Adaptive Phased Management facility is likely to be significantly less than the additional costs for long-term management for either of the other two approaches. • In regards to flexibility, it is reasonable to expect that science & technology and social values will change with time. These changes might mean that future generations may decide that a different management approach is warranted. Applying an alternative approach at some point in the future is easier with Centralized Storage or Storage at Nuclear Reactor Sites. This flexibility is available for Adaptive Phased Management as well, but only until year 325. However, it might be decided at that time (year 325) to extend the closure date. • Each of the four approaches places some risk in the hands of future generations. Storage at Nuclear Reactor Sites and Centralized Storage (above or below ground) require periodic re-handling of the used nuclear fuel during repackaging events far into the future, with associated financial liabilities, worker health & safety risks, environmental risks, and security risks. Deep Geological Disposal in the Canadian Shield is intended to be a long-term solution that reduces these risks for the most part to only the next few generations, assuming that normal conditions prevail. Although Adaptive Phased Management involves one more used nuclear fuel repackaging event compared to Deep Geological Disposal, the degree of added risk is marginal compared to the two storage approaches.	• For Centralized Storage (above or below ground) and Storage at Nuclear Reactor Sites, costs will continue far into the future as used nuclear fuel is re-packaged and storage facilities are re-built on a periodic basis. This means future generations bear the majority of the management costs for these two approaches. • However, the costs to monitor and take corrective measures, if and when required, are easier and likely less costly for the two storage management approaches, compared to a decommissioned and closed Deep Geological Disposal in the Canadian Shield facility (i.e., after year 154), or a decommissioned and closed Adaptive Phased Management facility after 325 years.

Measure or Indicator	Benefits	Risks	Costs
Interspecies Distributional Fairness • Human and non-human cost and benefits over time • Respect for life and biosphere	• All four management approaches would be constructed and would operate using best management practices. This will minimize adverse effects on humans, non-human biota and the environment. The key to ensuring interspecies distributional fairness is being able to effectively monitor, detect and mitigate adverse consequences in a timely manner. In this regard, Centralized Storage and Storage at Nuclear Reactor Sites allow the best opportunities for monitoring, detection and mitigation (if necessary) in the very long term. • Such consideration and protection for people and environment leaves greater flexibility to future generations to apply their value(s) about the biosphere, and plant and animal species into an alternative management approach that enhances their protection, if required. In comparison, Deep Geological Disposal in the Canadian Shield offers limited benefit in this context in the long term. Adaptive Phased Management offers a longer period of extended storage to enable research and development and enhanced monitoring to "prove" the technology and management plan for used nuclear fuel.	• All four management approaches have risks that could impact humans, non-human biota and the environment. • Location of the management approach is important. If a Centralized Storage, Adaptive Phased Management or a Deep Geological Disposal in the Canadian Shield facility were to be located in a rural or remote area, human interactions and consequences from adverse effects may be less compared to the possible impact on other species, at least in the short term. Over the long term, the population, environment and other dynamics in current rural or remote areas of Canada might change for a variety of reasons, including for example, population growth, and/or social preferences. This means that current decisions about location siting and possible interspecies effects will be strongly influenced by current conditions. • In this context, transportation of used nuclear fuel, which occurs in the short term, poses a risk to humans, non-human biota and the environment. This is only applicable to the Centralized Storage (above or below ground), Adaptive Phased Management and Deep Geological Disposal in the Canadian Shield. There are more risks associated with transportation routes that are longer.	• How society values the environment and interspecies existence will change with time. Consider for example, how the logging industry in Canada has transformed from "clear-cutting" (with its attendant negative impact on species preservation and rare habitats) a few decades ago, to one now of less invasive "selective logging" and the establishment of forest reserves in unique habitat areas. This is exemplified in British Columbia's Upper Walburn Valley[38], where preservation of a unique coastal temperate rainforest is taking precedence over certain logging activities. The cost of losing such a habitat is not possible to estimate in conventional terms.
Distributional Fairness • Decision Flexibility • Adherence to polluter pays principle • Transportation risks and other considerations • Distributional fairness of impacts on communities	• Deep Geological Disposal in the Canadian Shield and Adaptive Phased Management are considered long-term solutions, with closure of the underground facilities. In contrast, both Centralized Storage (above or below ground) and Storage at Nuclear Reactor Sites are storage approaches with greater ongoing and long-term financial liability, health & safety concerns, environmental and security risks and costs incurred by future generations. • Adaptive Phased Management is unique in its blend of a flexible centralized storage facility over approximately 300 years, and after extensive proof of concept activities, final placement of used nuclear fuel is conducted and then permanently closed. • Implementation of any of the four management approaches brings significant employment and income (wealth) benefits to the local host economic region, the host province, and to Canada as a whole (see analysis in Section 8). • The degree of benefit does vary considerably between the four management approaches. Deep Geological Disposal in the Canadian Shield offers a significant economic boom (i.e., $16 billion) to a host economic region and province, followed by a decline after year 59. In comparison, Storage at Nuclear Reactor Sites offers benefits to 6 economic regions simultaneously, with the greatest benefit occurring in south-central Ontario, where the majority of used nuclear fuel is currently located. Even though such benefits are cyclical, these cycles are far enough apart (i.e., approximately 300 years) that the host economic region(s) can not avoid a "boom and bust" type cycle and the attendant costs. • The degree of economic benefit varies by location. Rural and remote economic regions tend to capture less of the total economic benefits (i.e., employment, income and tax revenues) compared to the more populated urban centres. • Communities along the transportation route(s) to Deep Geological Disposal in the Canadian Shield or Centralized Storage (above or below ground) sites would incur some added risks but few, if any, benefits as transportation services and infrastructure may originate from outside these regions.	• In the near term, as noted above, transportation of used nuclear fuel in the case of Deep Geological Disposal in the Canadian Shield, Adaptive Phased Management or Centralized Storage (above or below ground) incur some added risks, whereas Storage at Nuclear Reactor Sites has no transportation risk because no off-site transportation is required. • In the long term, social values and technology change; as these values change, options for used nuclear fuel management change. In the event that new risks related to used nuclear fuel management are discovered for all four management approaches due to such changes, the management approach that is chosen has to be flexible (from a technology perspective), incorporate security (from a social value perspective), and consider institutional governance (long-term sustainability of government and institutions). For both Centralized Storage (above or below ground) and Storage at Nuclear Reactor Sites, social, financial, technological, and moral liabilities are placed on many future generations who will have to deal with the current generation's used nuclear fuel. • The Adaptive Phased Management also shifts some degree of risk and associated costs on near future generations, although the underground facility is currently planned to be decommissioned and closed within 325 years.	• In the event of an adverse effect on people or the environment, the distribution of social and personal costs are not equally shared. Most beneficiaries of nuclear energy today reside in urban centres throughout eastern Canada. If a future adverse event occurs at one location, then those people and sensitive environments located near the event will be most affected and will likely incur the brunt of social, environment and economic costs related to the event, its remediation and/or quality of life degradation. • In the long term, there may be no users of nuclear fuel, but future generations must continue to bear the cost and responsibility for long-term -management of used nuclear fuel. It has been discussed that the management approaches differ with respect to the distribution of benefits, but the distribution of costs is highly skewed to future generations for the two storage approaches. In addition, communities in rural and remote economic regions will likely bear a higher social and financial cost, in proportion to urban centres, for added infrastructure during construction phases, and will also have to deal with the cost of the inevitable economic bust when the initial phase(s) of the chosen management approach is complete.

[38] *The Upper Walburn Valley –Protect It Now!*, Western Canada Wilderness Committee, www.wildernesscommitteevictoria.org/campaigns_walburn.php, 2004

Measure or Indicator	Benefits	Risks	Costs
Opportunity to Influence Decision Outcomes & Engagement in Decision Making • Governance model(s) • Status of aboriginal land claims • Capacity for Public Engagement • State of sustainable livelihoods capitals • Identification of appropriate investments and mitigation measures in the five capitals	• The NWMO is committed to a process of full and open community engagement and consultation on all the issues relating to the management of used nuclear fuel. Currently, this process is independent of management approach and location. It is sensitive to issues relating to the eight objectives articulated by the NWMO Assessment Team.	• Community and stakeholder engagement is a worthwhile and valuable component to deciding on an appropriate management approach for used nuclear fuel. However, there are risks that should be considered, including for example: – New ideas and options are bound to be expressed, that if not fully accounted for in subsequent discussions, might lead to stakeholder disenchantment and disengagement with the process; and – No matter how much effort and support is put into a community engagement process, it must be recognized that not all stakeholders will be happy or "buy-in" to the final decision. • These and other risks of community engagement can be minimized with a comprehensively open and easily accessible consultation and engagement process, such as the process implemented for the MacKenzie Valley Pipeline[39]. What Thomas Berger demonstrated is that it is possible to achieve an effective agreement on a specific course of action. Although not everyone might agree with that action, everyone can clearly see the process and understand the influencing factors leading to the final decision.	• There are certain issues that need to be addressed prior to finalization of a used nuclear fuel management approach. One element clearly identified by the NWMO Assessment Team is community engagement and participation in the decision-making processes. This is not as easy as simply inviting stakeholders to meetings. Stakeholders at all levels and from many locations lack the training, education, support institutions, and financial resources to participate in a meaningful and constructive way, particularly those who reside in rural and remote regions of Canada. These issues need to be resolved first, and it will not likely be a process that can be done quickly. The need for community engagement and participation in the decision-making processes is independent of management approach and possible site location(s). • Consider for example the following: – Aboriginal land claims need to be accounted for in any future discussions regarding the decision process for a preferred management approach and location. In a recent ruling by the Supreme Court of Canada (November 18 2004)[40], it was stated that no projects involving a formal environmental assessment can proceed without addressing how aboriginal land claims will be addressed or accounted for. – Moreover, Aboriginal communities within all of the illustrative economic regions examined in this study have a relatively low adaptive capacity and will likely face far greater challenges in the basic process of engaging with the NWMO than will non-aboriginal populations.

[39] Berger, Thomas R., *Northern Frontier, Northern Homeland: The Report of the Mackenzie valley Pipeline Inquiry*, Volume 1, Minister of Supply and Services Canada, 1977.
[40] According to this new ruling, governments have a legal duty to consult with First Nations to some extent about the development of disputed land. This landmark ruling will have a major impact on how governments and industry deal with First Nations before making land-use decisions. The court ruled that the amount of consultation depends on the strength and seriousness of the land claim and the effect on the land in use.
But Chief Justice Beverley McLachlin, who wrote the decision for the court, said aboriginal claimants must not "frustrate the Crown's reasonable good faith attempts" at consultation. "Nor should they take unreasonable positions to thwart governments from making decisions or acting in cases where, despite meaningful consultation, agreement is not reached."

12.0 SUMMARY DISCUSSION

The preceding sections of this report have evaluated the benefits, risks and costs of the Adaptive Phased Management Approach using the eight guiding objectives identified by the NWMO Assessment Team. This section provides a summary discussion of the salient advantages of Adaptive Phased Management relative to the other three approaches described in the Technical Report (GAL-GLL, 2005).

The comparison summary, presented in Table 12-1, demonstrates that Adaptive Phased Management offers enhanced value when compared to the other three approaches. Specifically, it builds on the strong security features and long-term solution of the Deep Geological Disposal in the Canadian Shield approach and leverages many of the adaptability and fairness features of the Storage of Nuclear Reactor Sites and Centralized Storage Approaches. In the meantime, economic benefits are maximized in the near term, when there is greater confidence in financial surety.

Significantly, the Adaptive Phased Management Approach extends the operational activities of the deep long-term isolation facility for a period of time. This enables adjacent communities needed time for investment in social, human, physical, financial and environmental capitals that will lead to enhanced participation in the project and an ability to better protect themselves from adverse consequences. In addition, delaying the closure of the deep isolation facility allows time for proof-of-concept.

TABLE 12-1:
COMPARISON SUMMARY – ADAPTIVE PHASED MANAGEMENT VERSUS OTHER THREE APPROACHES

Advantages of Adaptive Phased Management (Compared with Others)	Disadvantages of Adaptive Phased Management (Compared with Others)
Public Health and Safety	
• Adaptive Phased Management has the advantages of Deep Geological Disposal in the Canadian Shield because there are potentially less people at risk since it may be located in economic regions with lower population densities than Storage at Nuclear Reactor Sites or Centralized Storage (above or below ground), assuming current population patterns continue.	Before decommissioning and closure (year 325), the Adaptive Phased Management Approach shares some of the limitations of Storage at Nuclear Reactor Sites or Centralized Storage (above or below ground) as it could result in radiation exposure to humans if institutional control is not maintained. However, this represents a much lower risk for Adaptive Phased Management.
• In common with all approaches requiring relocation of the used nuclear fuel, the potential transportation risks are greater for greater transportation distances. Following closure in year 325, Adaptive Phased Management has the advantages of Deep Geological Disposal in the Canadian Shield in the long-term in the event of a loss of institutional control or inadvertent intrusions.	
• The Adaptive Phased Management Approach, similar to Deep Geological Disposal in the Canadian Shield, relies on the host geologic formation to control the movement of radioactivity for the long-term. In contrast, Storage at Nuclear Reactor Sites or Centralized Storage (above or below ground) relies on active human management and institutional controls to prevent the movement of radioactivity.	

Advantages of Adaptive Phased Management (Compared with Others)	Disadvantages of Adaptive Phased Management (Compared with Others)
Worker Health and Safety	
• Similar to Deep Geological Disposal in the Canadian Shield, Adaptive Phased Management offers the advantage of requiring few workers in the long term, other than those involved with monitoring. Storage at Nuclear Reactor Sites and Centralized Storage both require a large number of workers over the long term.	• Similar to Deep Geological Disposal in the Canadian Shield, Adaptive Phased Management involves a larger workforce to achieve all used nuclear fuel in place compared with Storage at Nuclear Reactor Sites or Centralized Storage. Further, because of a longer active management period, Adaptive Phased Management requires a larger workforce in the near term until closure (year 325) than Deep Geological Disposal in the Canadian Shield. • Injuries and fatalities due to transportation could be incurred for Adaptive Phased Management, similar to Deep Geological Disposal in the Canadian Shield and Centralized Storage. The risk of injury is greater for longer transportation distances.
Security	
• Adaptive Phased Management offers similar advantages of Deep Geological Disposal in the Canadian Shield with respect to controlling the access to used nuclear fuel in the long term. These advantages result from the robustness of engineered and geological barriers and fewer used nuclear fuel repackaging activities.	• Although offering more security than Storage at Nuclear Reactor Sites or Centralized Storage, Adaptive Phased Management is less secure than Deep Geological Disposal in the Canadian Shield because of a longer active management period prior to closure. • Adaptive Phased Management has similar risks associated with transportation as Deep Geological Disposal in the Canadian Shield and Centralized Storage. These risks are greater for longer transportation distance, but can be managed.
Economic Viability	
• Similar to Deep Geological Disposal in the Canadian Shield, Adaptive Phased Management has the majority of costs in the near term. Both approaches have much lower cumulative annual costs in the long term compared with Storage at Nuclear Reactor Sites or Centralized Storage. Costs in the near term have less uncertainty and a higher confidence that the required financial resources will be available when needed.	• The approximate present value cost for Adaptive Phased Management is similar to that of Deep Geological Disposal in the Canadian Shield. Both are significantly more than the present value cost estimates for Storage at Nuclear Reactor Sites or Centralized Storage.
• Adaptive Phased Management balances the risks that the required financial resources are available when needed, with the benefits of allowing time for new technology development and proof of concept. In addition, Adaptive Phased Management preserves opportunities for decision making to future generations up to year 325 without compromising the responsibility of the current generation to identify a solution.	

Advantages of Adaptive Phased Management (Compared with Others)	Disadvantages of Adaptive Phased Management (Compared with Others)
Community Well-Being	
• Similar to Deep Geological Disposal in the Canadian Shield, Adaptive Phased Management creates much larger economic benefits (employment, income and taxes) in the near term than Storage at Nuclear Reactor Sites or Centralized Storage. While the economic benefits of Deep Geological Disposal in the Canadian Shield and Adaptive Phased Management are generally similar, the benefits from Adaptive Phased Management are spread out over a longer time period than for Deep Geological Disposal in the Canadian Shield. This allows for a more sustainable community by reducing some of the risks of a boom and bust economy.	
• Locations for Deep Geological Disposal in the Canadian Shield are generally more remote regions that have fewer of the necessary facilities and capacities to cope with the "shock" and/or take advantage of opportunities from such a large project. Adaptive Phased Management has more flexibility in location because it is not limited to the Canadian Shield, and it can extend over greater time.	
• Adaptive Phased Management, like Deep Geological Disposal in the Canadian Shield and Centralized Storage, requires investment in local community services, infrastructure and institutions to enable effective and meaningful discussion. However, the flexibility in location afforded by the Adaptive Phased Management Approach offers some advantages over Deep Geological Disposal in the Canadian Shield because it can include communities in more urban areas.	
Environmental Integrity	
• Any adverse environmental effects during normal or off-normal conditions, including during transportation, would be determined more by specific features of the ecozone and economic region rather than by a particular approach.	
• Similar to Deep Geological Disposal in the Canadian Shield, Adaptive Phased Management has limited opportunities for effective long term monitoring once the underground facility is decommissioned and closed because of the nature of an underground facility. However, Adaptive Phased Management offers an advantage compared with Deep Geological Disposal in the Canadian Shield by allowing for preclosure monitoring to year 325 versus year 154 for Deep Geological Disposal in the Canadian Shield. Future generations may decide not to decommission and close the facility by year 325 given new knowledge and/or technologies.	
• Notwithstanding the effectiveness of monitoring, Adaptive Phased Management includes, as part of the concept, provision for long-term monitoring following closure.	
Adaptability	
• Adaptive Phased Management offers the benefit of a long term solution while providing easy access and on-going monitoring capability with the potential benefits of allowing technical enhancements for several hundreds of years prior to closure (at year 325).	
• Adaptive Phased Management allows more time for active monitoring compared to Deep Geological Disposal in the Canadian Shield that can be used to prove the technology and adapt new technological developments should they arise in the near term. If satisfied with the results of the extended monitoring and proof of concept, future generations can decide to proceed with long-term isolation or implement an alternative approach. This extended storage and monitoring period (approximately 210 years), with the advantage of providing proof of concept, reduces the potential requirement for the retrieval from a decommissioned and closed underground facility.	

Advantages of Adaptive Phased Management (Compared with Others)	Disadvantages of Adaptive Phased Management (Compared with Others)
• Similar to Deep Geological Disposal in the Canadian Shield, the Adaptive Phased Management Approach is less dependent on institutions and governance in the long term because actions are not required after closure other than long-term monitoring. Over the long term, it is likely that institutions and governance will change. Storage at Nuclear Reactor Sites and Centralized Storage require on-going active management and financial resources over the very long term, with the associated institutional controls and governance.	
• Adaptive Phased Management offers an advantage over Deep Geological Disposal in the Canadian Shield by allowing both current and near-current generations to participate in the selection and design of the long-term approach before it is fully implemented. This ensures that an open and transparent process continues in relation to monitoring and new knowledge about how best to deal with used nuclear fuel involves those who were responsible for producing the used nuclear fuel and those who are responsible for fully implementing the selected management approach.	
Fairness	
• Assuming the facility operates as designed, the Adaptive Phased Management Approach, like Deep Geological Disposal in the Canadian Shield, incurs the majority of its costs in the near term, thus limiting the financial liabilities and financial surety to current and near-current generations. This ensure that as much of the responsibility as practicable is borne by the generation that benefited from the nuclear power that produced the used nuclear fuel.	
• Adaptive Phased Management, like Deep Geological Disposal in the Canadian Shield, has a higher degree of certainty and confidence that the financial resources required for implementation will be available when needed. This offers the advantage of not unfairly burdening future generations with uncertain and unending financial liabilities.	
• Adaptive Phased Management offers an added benefit compared to Deep Geological Disposal in the Canadian Shield because it incorporates 210 years of monitoring and proof of concept prior to a future generation deciding whether or not to implement the closure of the facility. This provides an advantage of fairness by allowing future generations to take responsibility for the decisions that affect them.	

APPENDIX A

ADDITIONAL MAPS AND FIGURES

TABLE 2-1:
CONCEPTUAL DESIGN AND COST ESTIMATE REPORTS FOR LONG TERM MANAGEMENT OF USED NUCLEAR FUEL

Interim Storage And Retrieval At Existing Reactor Sites

Joint Waste Owners, March 2004. *Costs of Alternative Approaches for the Long-Term Management of Canada's Nuclear Fuel Waste, Deep Geologic Disposal Approach*. A submission to the Nuclear Waste Management Office by Ontario Power Generation, Hydro-Quebec, New Brunswick Power and Atomic Energy of Canada Limited. Rev 01. **(JWO, 2004a)**

Joint Waste Owners, March 2004. *Costs of Alternative Approaches for the Long-Term Management of Canada's Nuclear Fuel Waste, Centralized Extended Storage Approach.* A Submission to the Nuclear Waste Management Office by Ontario Power Generation, Hydro-Quebec, New Brunswick Power and Atomic Energy of Canada Limited. Rev 02. **(JWO, 2004b)**

Transportation To Central Facility

COGEMA LOGISTICS, May 2003. *Conceptual Designs for Transportation of Used Nuclear Fuel to a Centralised Facility*. Report of a Study carried out for Ontario Power Generation, New Brunswick Power, Hydro Quebec and Atomic Energy of Canada Limited. Ref. 500276-B-005. Rev.00 **(COGEMA, 2003a)**

COGEMA LOGISTICS, September 2003. *Cost Estimate for Transportation of Used Nuclear Fuel to a Centralised Facility.* Report of a Study carried out for Ontario Power Generation, New Brunswick Power, Hydro Quebec and Atomic Energy of Canada Limited. Ref. 500276-B-010 Rev. 00 **(COGEMA, 2003b)**

Extended Storage at Central Facility

CTECH Radioactive Materials Management, April 2003. *Conceptual Designs for Four Centralized Extended Storage Facility Alternatives for Used Nuclear Fuel*. Report of a Study carried out for Ontario Power Generation, New Brunswick Power, Hydro Quebec and Atomic Energy of Canada Limited. 1105/MD18084/REP/11. **(CTECH, 2003a)**

CTECH Radioactive Materials Management, May 2003. *Cost Estimates for Four Centralized Extended Storage Facility Alternatives for Used Nuclear Fuel.* Report of a Study carried out for Ontario Power Generation, New Brunswick Power, Hydro Quebec and Atomic Energy of Canada Limited. 1105/MD18084/REP/11. **(CTECH, 2003b)**

RWE NUKEM Limited, November 2004. "*Centralized Extended Storage in Sedimentary Rock, High-Level Review*" Report of a Study carried out for the Nuclear Waste Management Organization. 89148/REP/05 Issue 1. **(RWE NUKEM, 2004a)**

Long-Term Isolation At Central Facility

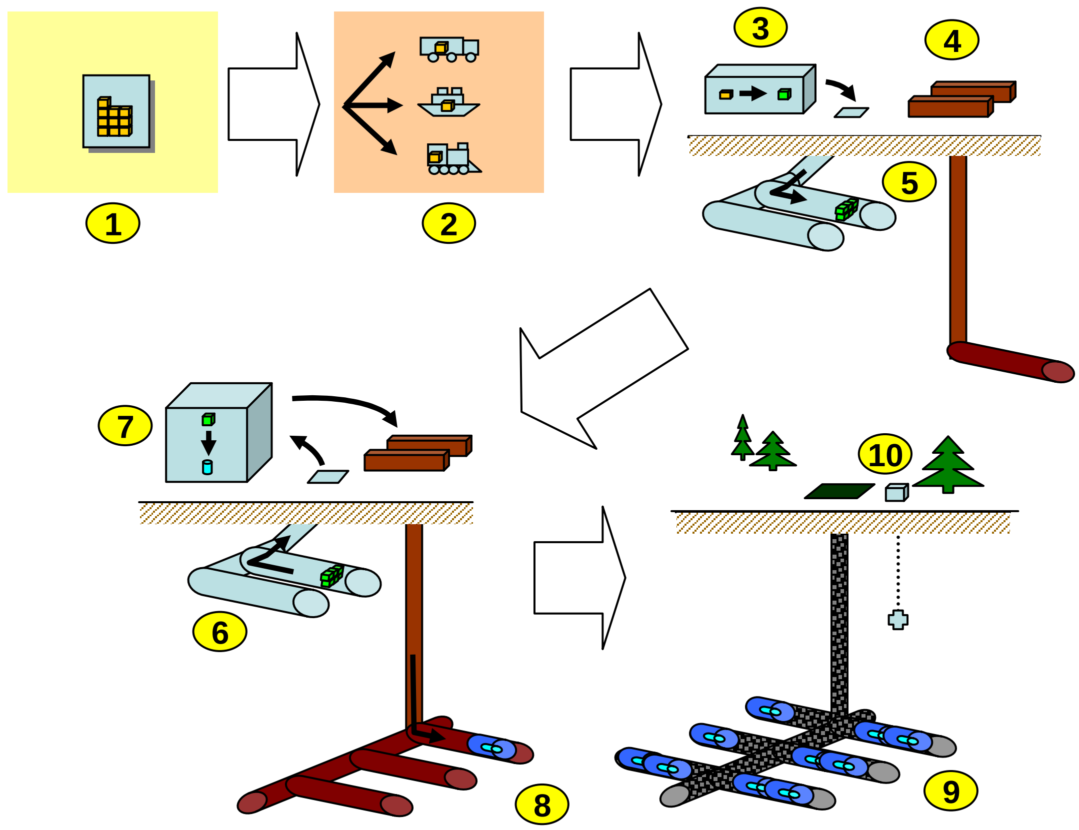
CTECH Radioactive Materials Management, December 2002. *Conceptual Design for a Deep Geologic Repository for Used Nuclear Fuel*. Report of a Study carried out for Ontario Power Generation, New Brunswick Power, Hydro Quebec and Atomic Energy of Canada Limited. 1106/MD18085/REP/01. **(CTECH, 2002)**

CTECH Radioactive Materials Management, September 2003. *Cost Estimate for a Deep Geologic Repository for Used Nuclear Fuel.* Report of a Study carried out for Ontario Power Generation, New Brunswick Power, Hydro Quebec and Atomic Energy of Canada Limited. 1106/MD18085/REP/02. **(CTECH, 2003c)**

RWE NUKEM Limited, November 2004. "Deep Geological Repository in Sedimentary Rock, High-Level Review "Report of a Study carried out for the Nuclear Waste Management Organization. 89148/REP/04, Issue 1. **(RWE NUKEM, 2004b)**

Adaptive Phased Management of Used Nuclear Fuel

Figure 2-1



1. Interim storage at reactor sites
2. Transportation to a central site
3. Repackaging, as necessary, into new dry storage containers
4. Extensive R&D program
5. Shallow below-ground storage
6. Retrieval of used fuel from storage
7. Repackaging into Used Fuel Containers (UFCs)
8. Emplacement of UFCs in long-term isolation facility; extended monitoring
9. Closure of long-term isolation facility
10. Post-closure monitoring

Date: April 2005

Project: 05-1112-002

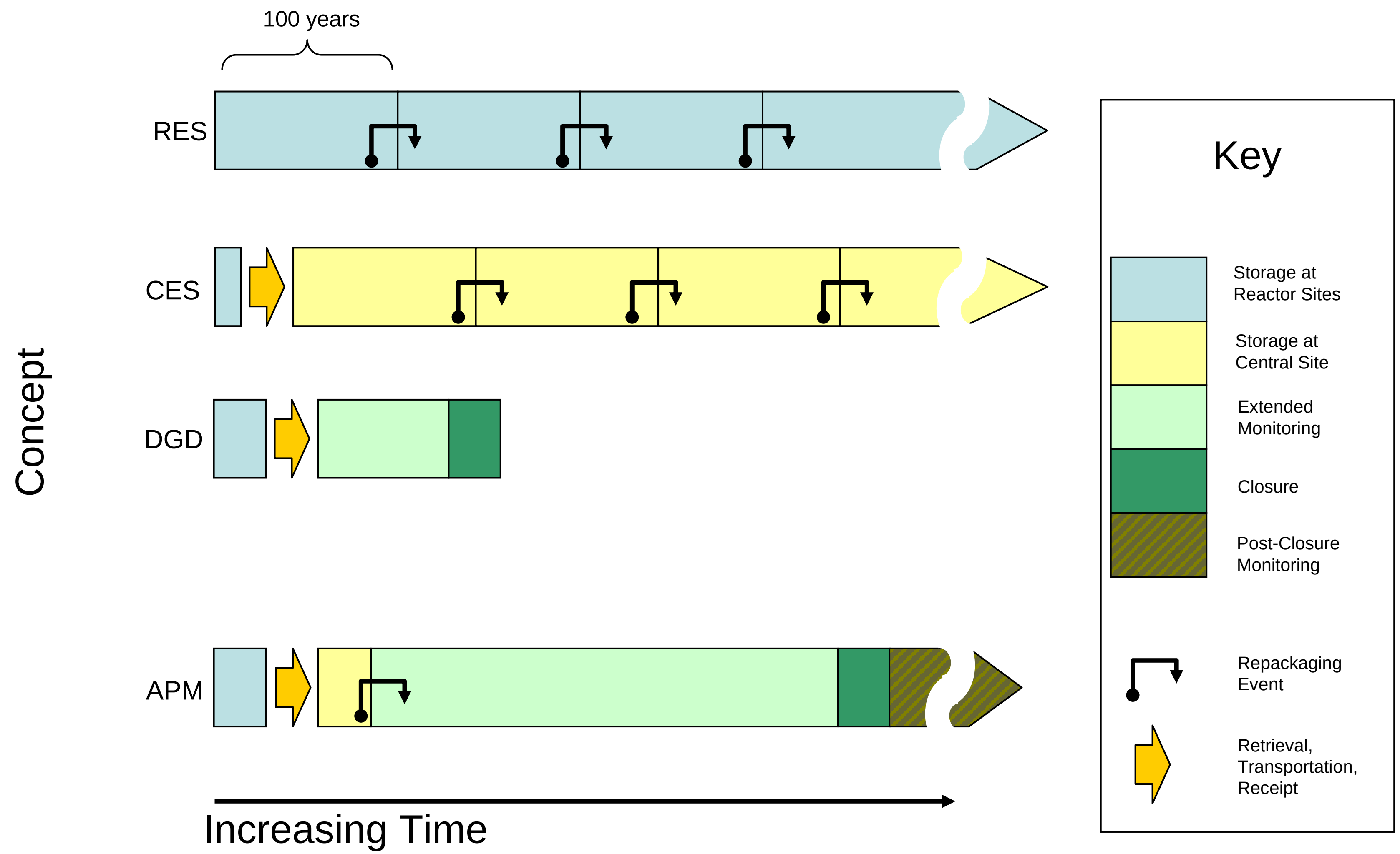
Golder Associates

Drawn: RPC

Chkd: CJPS

High-Level Adaptive Phased Management Approach Schedule Compared to those of Previously Assessed Concepts

Figure 2-2



Date: April 2005

Project: 05-1112-002

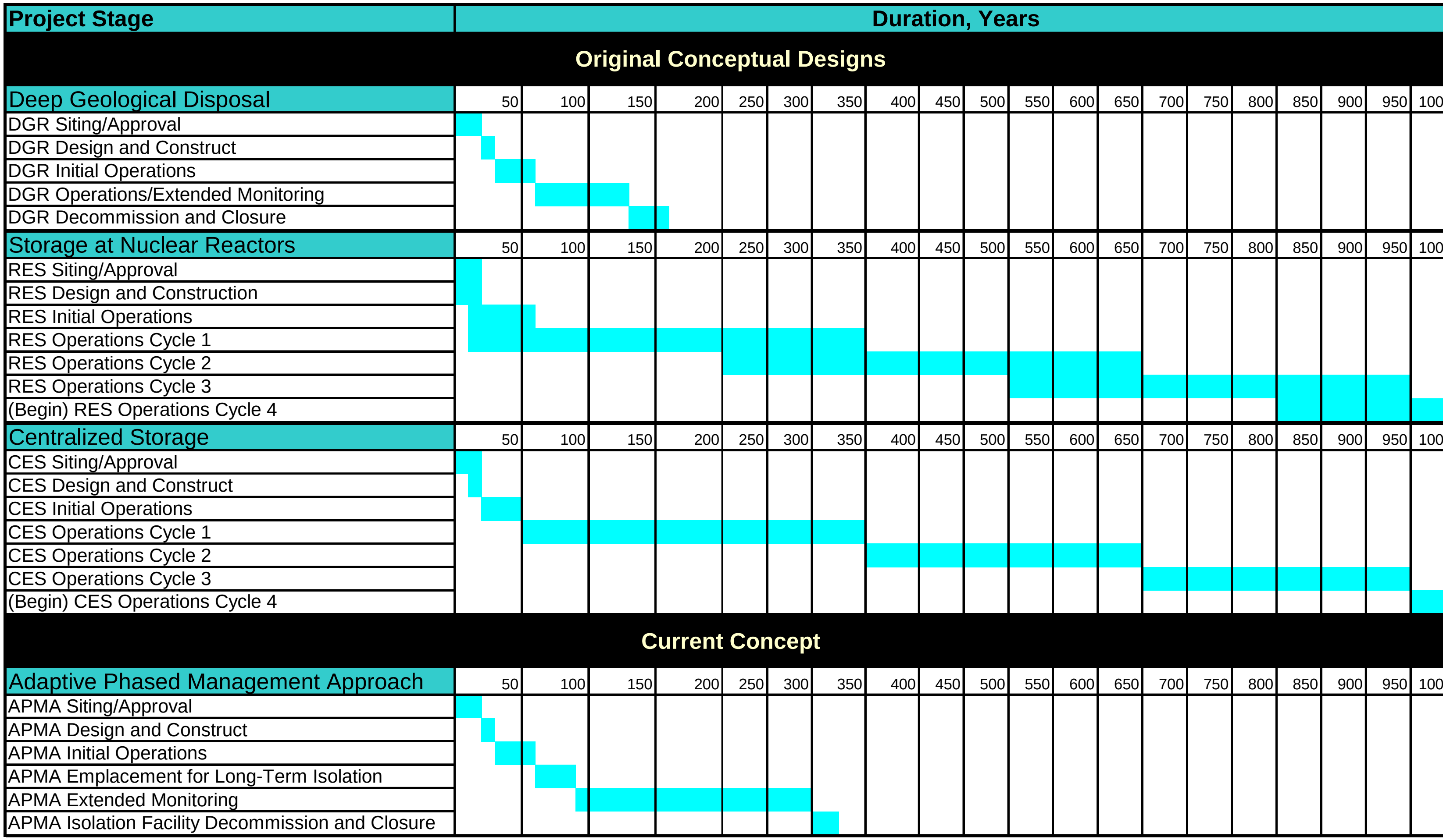
Golder Associates

Drawn: RPC

Chkd: CJPS

Project Stage Schedule Comparison

Figure 2-3



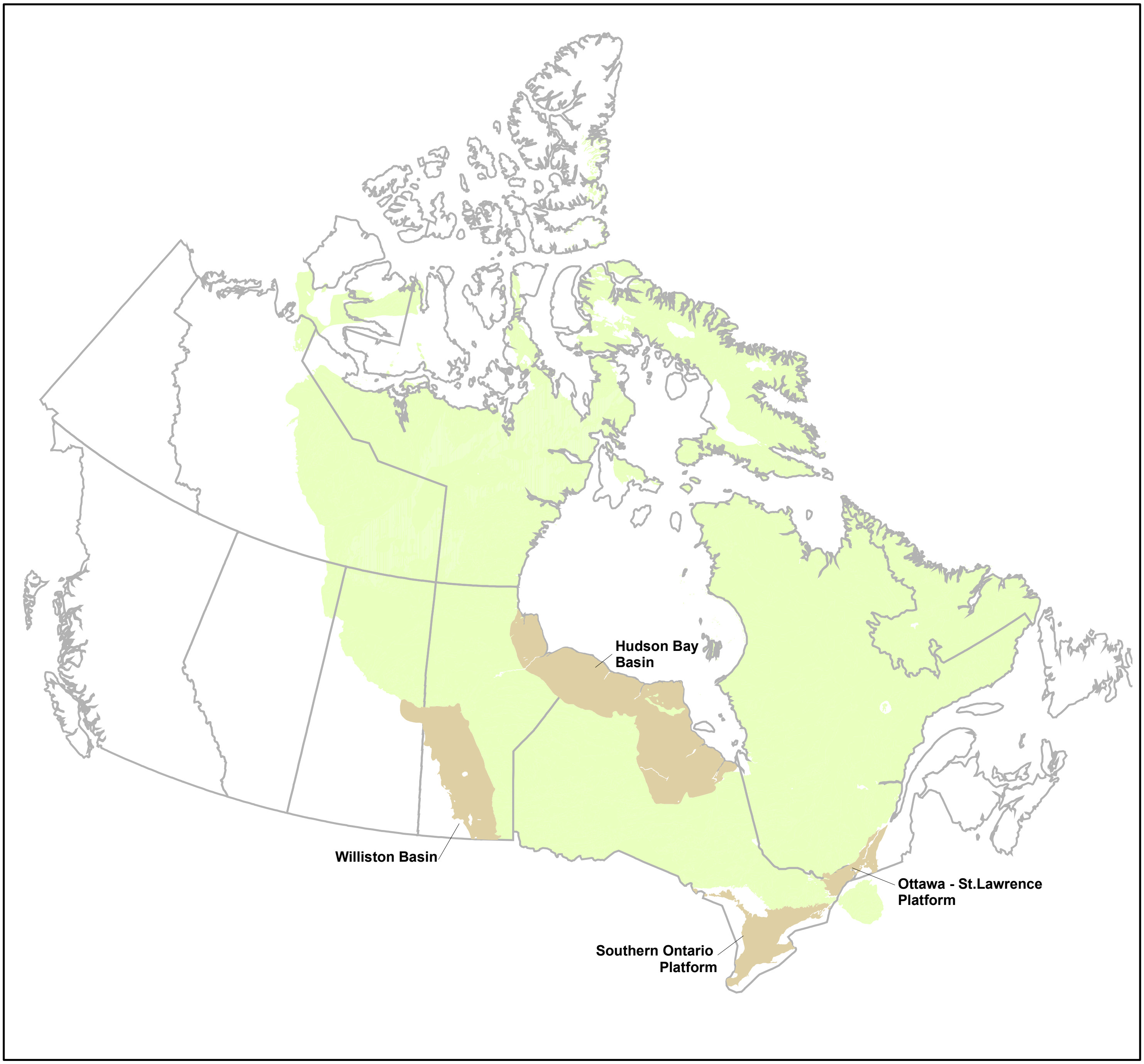
Date: April 2005

Project: 05-1112-002

Golder Associates

Drawn: RPC

Chkd: CJPS



LEGEND

- Selected Ordovician Sedimentary Formation
- Canadian Shield

N

0 200 400 600 800
Kilometres

REFERENCE

Surfiicial Geology Mapping for the Canadian Shield
from the Geological Survey of Canada Open File 3046
Bibliography for surficial geology mapping in Canada,
R.J. Fulton, L. Maurice, and K.F.,Betrand, August 1995.
Digital base supplied by the National Atlas
Information Service, Geomatics Canada, with modifications
by the Geological Survey of Canada.

Datum: NAD27 Projection: Lambert Conic Conformal

PROJECT

Nuclear Waste Management Organization

TITLE

Canadian Shield and Selected Ordovician Sedimentary Formations

Golder Associates
Mississauga, Ontario

PROJECT No. 05-1112-002			SCALE 1:27,750,000	REV. 2
DESIGN	CC	28 Feb 2005	FIGURE: 2-4	
GIS	PM	25 Apr. 2005		
CHECK	CS	25 Apr. 2005		
REVIEW				

G:\Projects\2005\05-1112-002_NWMO\GIS\MXDs\Draft\April25\Figure2_4_CanShield_and_Ordovician_Sed.mxd

From Whiteshell to:	Distance (km)
Northern (4760)	1586
Nord-du-Quebec (2490)	2850
Northeast (3590)	1409
Stratford - Bruce Peninsula (3580)	3961

Distances were calculated to the centroid of the Economic Regions, using the Trans-Canada Highway and other major routes. Where no major road exists, straight line distances were calculated. Routes are intended to be illustrative only.

Travel from Whiteshell | Figure 6.4-1

Assessment of Costs, Benefits and Risks of Management Approaches by Economic Region

Project 05-1112-002, April 2005

From Bruce to:	Distance (km)
Northern (4760)	3575
Nord-du-Quebec (2490)	2035
Northeast (3590)	874
Stratford - Bruce Peninsula (3580)	57

Distances were calculated to the centroid of the Economic Regions, using the Trans-Canada Highway and other major routes. Where no major road exists, straight line distances were calculated. Routes are intended to be illustrative only.

Travel from Bruce | Figure 6.4-2

Assessment of Costs, Benefits and Risks of Management Approaches by Economic Region

Project 05-1112-002, April 2005

From Pickering to:	Distance (km)
Northern (4760)	3527
Nord-du-Quebec (2490)	1856
Northeast (3590)	825
Stratford - Bruce Peninsula (3580)	246

Distances were calculated to the centroid of the Economic Regions, using the Trans-Canada Highway and other major routes. Where no major road exists, straight line distances were calculated. Routes are intended to be illustrative only.

Travel from Pickering | Figure 6.4-3

Assessment of Costs, Benefits and Risks of Management Approaches by Economic Region

Project 05-1112-002, April 2005

Gartner Lee
Golder Associates

From Darlington to:	Distance (km)
Northern (4760)	3556
Nord-du-Quebec (2490)	1829
Northeast (3590)	853
Stratford - Bruce Peninsula (3580)	303

Distances were calculated to the centroid of the Economic Regions, using the Trans-Canada Highway and other major routes. Where no major road exists, straight line distances were calculated. Routes are intended to be illustrative only.

Travel from Darlington — Figure 6.4-4

Assessment of Costs, Benefits and Risks of Management Approaches by Economic Region

Project 05-1112-002, April 2005

From Chalk River to:	Distance (km)
Northern (4760)	3429
Nord-du-Quebec (2490)	1628
Northeast (3590)	728
Stratford - Bruce Peninsula (3580)	656

Distances were calculated to the centroid of the Economic Regions, using the Trans-Canada Highway and other major routes. Where no major road exists, straight line distances were calculated. Routes are intended to be illustrative only.

Travel from Chalk River | Figure 6.4-5

Assessment of Costs, Benefits and Risks of Management Approaches by Economic Region

Project 05-1112-002, April 2005

Gartner Lee
Golder Associates

Travel from Gentilly — Figure 6.4-6

Assessment of Costs, Benefits and Risks of Management Approaches by Economic Region

Project 05-1112-002, April 2005

Gartner Lee · Golder Associates

From Gentilly to:	Distance (km)
Northern (4760)	3947
Nord-du-Quebec (2490)	1786
Northeast (3590)	1245
Stratford - Bruce Peninsula (3580)	894

Distances were calculated to the centroid of the Economic Regions, using the Trans-Canada Highway and other major routes. Where no major road exists, straight line distances were calculated. Routes are intended to be illustrative only.

From Point Lepreau to:	Distance (km)
Northern (4760)	4728
Nord-du-Quebec (2490)	2567
Northeast (3590)	2026
Stratford - Bruce Peninsula (3580)	1675

Distances were calculated to the centroid of the Economic Regions, using the Trans-Canada Highway and other major routes. Where no major road exists, straight line distances were calculated. Routes are intended to be illustrative only.

Travel from Point Lepreau Figure 6.4-7

Assessment of Costs, Benefits and Risks of Management Approaches by Economic Region

Project 05-1112-002, April 2005

Gartner Lee Golder Associates

Figure 7.3-1: Total Cash Flow, Adaptive Phased Management Approach (including Interim Storage, Retrieval and Transport Costs)

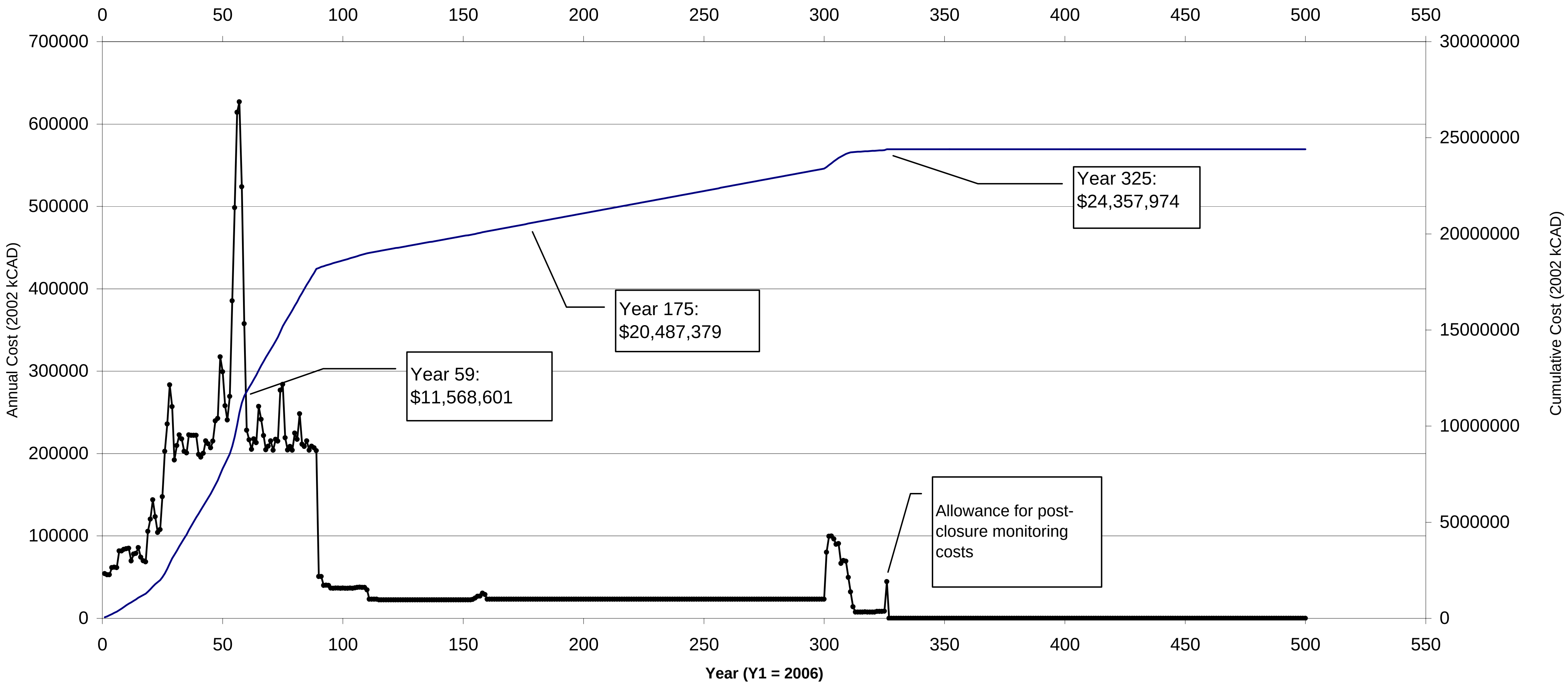
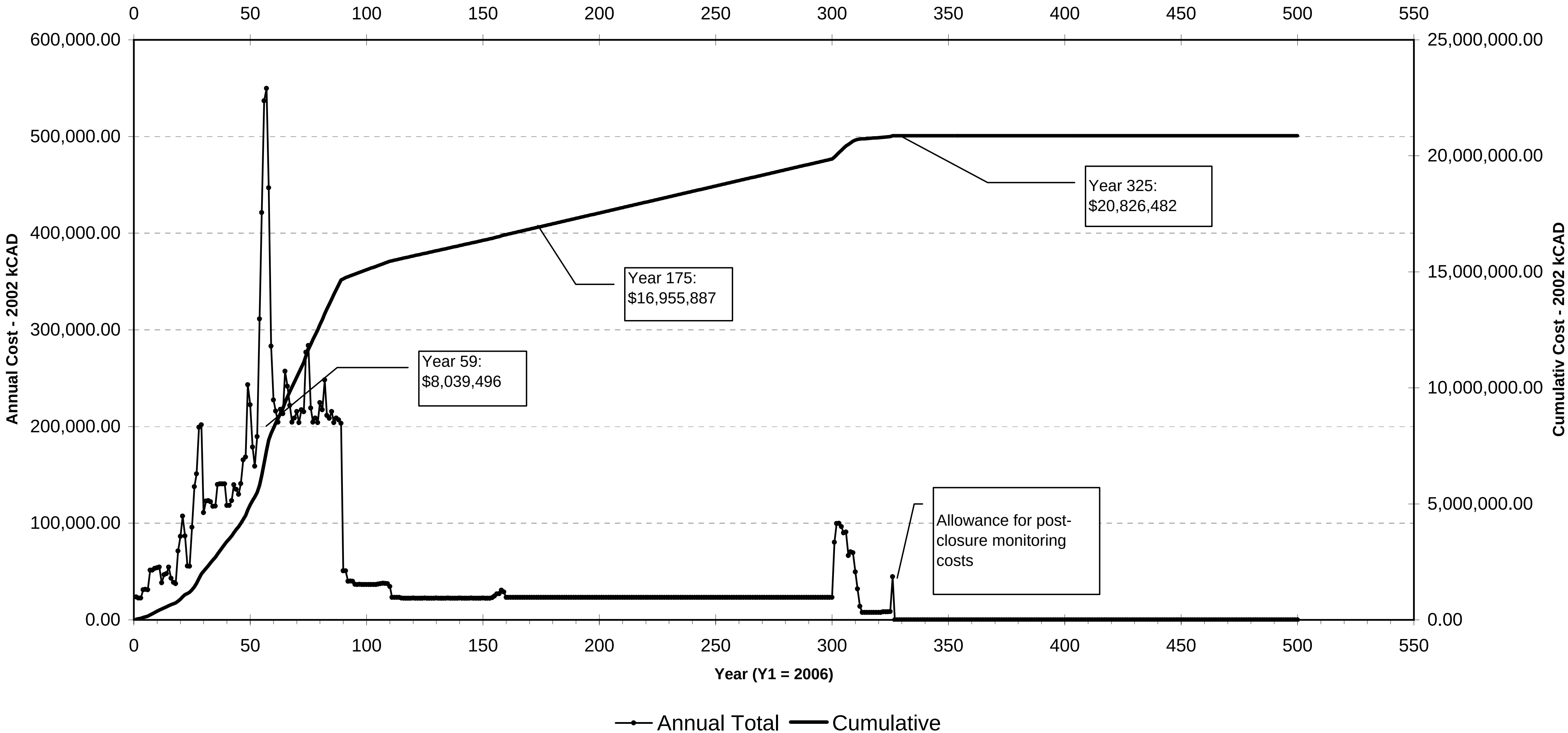


Figure 7.3-2: Total Cash Flow, Adaptive Phased Management Approach (not including Interim Storage, Retrieval and Transport Costs)



APPENDIX B

SUMMARY OF ESTIMATED TOTAL (NON-DISCOUNTED) CASH FLOWS AND ESTIMATED PRESENT VALUE OF COSTS

Estimated Total (non-discounted) Cash Flows and Estimated Present Value of Costs

Management Approach	Joint Waste Owner Single-Cycle Estimates (First ~350 Years)		GAL/GLL Multiple-Cycle Estimates (First ~1000 Years)	
	Total Cost (2002B$)	Present Value (January 2004B$)	Total Cost (2002B$)	Present Value (January 2004B$)
Option 1: Deep Geological Disposal	16.2	6.2	16.2	6.2
Option 2: Storage at Nuclear Reactor Sites				
Current Technology	17.6	2.3	-	-
New Above Ground Technology	25.7	4.4	68.4	4.1
New Below Ground Technology	21.6	3.6	-	-
Option 3: Centralized Storage				
Casks/Vaults in Storage Buildings	15.7	3.1	-	-
Surface Modular Vaults	20.0	3.8	47.0	3.8
Casks/Vaults in Shallow Trenches	18.7	3.6	-	-
Casks in Rock Caverns	17.1	3.4	40.6	3.4
Option 4: Adaptive Phased Management				
With Shallow Underground Storage	-	-	24.4	6.1
Without Shallow Underground Storage	-	-	22.6	5.1

Notes:
These cost estimates are approximate and include allowances for interim storage, retrieval and transportation, where applicable.
These cost estimates are based on information developed at a conceptual design level (Option 1, 2 and 3) and at a preliminary level (Option 4).
Actual costs would vary and would depend on a number of factors, as described in the main text of this report.

Cost estimates for Interim Storage and Retrieval for Option 4 - without Shallow Underground Storage are presented in the attached memorandum dated April 22, 2005 from Ontario Power Generation.

ONTARIOPOWER GENERATION

700 University Avenue Toronto, Ontario M5G 1X6

MEMORANDUM

Mr. P. Lovie
Sr. Research Analyst
Nuclear Waste Management Organization
49 Jackes Avenue, First Floor
Toronto, ON, M4T 1E2

Date: 22/4/2005

Subject: Interim Storage and Retrieval Cost Estimate for DGR Option #4

Dear Paul:

We have completed a high level cost estimate for the interim storage and retrieval costs associated with a deferred in-service date of DGR to 2065. This deferral will increase the period of interim storage by 30 years. The following table summarizes the results including a comparison to storage and retrieval estimates prepared for the Baseline DGR in 2035.

		Base DGR	Option 4	Delta
Retrieval	2002 k$	$585,000	$ 924,574	$ 339,574
	Jan 2004 PVk$	$232,000	$180,647	$(51,353)
Interim Storage	2002 k$	$1,795,000	$2,580,172	$785,172
	Jan 2004 PVk$	$1,187,000	$1,467,319	$280,319
Total	2002 k$	**$2,380,000**	**$3,504,746**	$1,124,746
	Jan 2004 PVk$	**$1,419,000**	**$1,647,966**	**$228,966**

The assumptions associated with Option 4 include continued dry and wet storage of fuel locally, subsequent transfer of wet fuel to local dry storage, and retrieval and shipment of fuel from dry storage to disposal from 2065 to 2095.

Please contact me at your convenience if you have any further questions.

Sincerely,

John Kennard
Section Manager – Life Cycle Estimating
Nuclear Waste Liabilities Department
NWMD

cc:	K. Nash	H17-G25
	J. van den Hengel	H17-E24