NUCLEAR WASTE MANAGEMENT ORGANIZATION
SOCIÉTÉ DE GESTION DES DÉCHETS NUCLÉAIRES

Choosing a Way Forward

The Future Management of Canada's Used Nuclear Fuel

Draft Study Report

Be Involved

NWMO invites all interested individuals and organizations to get involved. Your views deserve to be heard.

Make a submission or share your comments with other interested Canadians and make your views known by August 31, 2005, at our website, www.nwmo.ca.

Review our public engagement plans, discussion documents, reports and research, which are available on our website at www.nwmo.ca.

Or contact us at:
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Our final report and recommendations must be submitted to the Minister of Natural Resources Canada by November 15, 2005.

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VISION, MISSION AND VALUES

VISION

Our vision is the long-term management of Canada's nuclear waste in a manner that safeguards people and respects the environment, now and in the future.

MISSION

The purpose of the NWMO is to develop collaboratively with Canadians a management approach for the long-term care of Canada's used nuclear fuel that is socially acceptable, technically sound, environmentally responsible and economically feasible.

VALUES

The fundamental beliefs that will guide us in our work include:

INTEGRITY

We will conduct ourselves with openness, honesty and respect for all persons and organizations with whom we deal.

EXCELLENCE

We will pursue the best knowledge, understanding and innovative thinking in our analysis, engagement processes and decision-making.

ENGAGEMENT

We will seek the participation of all communities of interest and be responsive to a diversity of views and perspectives. We will communicate and consult actively, promoting thoughtful reflection and facilitating a constructive dialogue.

ACCOUNTABILITY

We will be fully responsible for the wise, prudent and efficient management of resources and be accountable for all of our actions.

Foreword

Choosing A Way Forward is the third major report that we have published over the course of our study. We made a commitment to share our thinking as it evolved and was shaped by our investigations and interaction with Canadians. The first documents articulated the issues, tested ideas and reported back what we were hearing.

This report is of a different character. It is now time to reflect our synthesis of ideas from the two years of our engagement with citizens and specialists, and to propose a course of action. The NWMO alone is responsible for these conclusions, which we believe to be responsive to the state of current knowledge and our understanding of the values of those who contributed to the dialogue.

We were asked to recommend an approach for the long-term management of used nuclear fuel in Canada. Part One of this report presents such a proposal, and outlines the factors that influenced us in reaching our conclusions. Parts Two and Three describe the journey we undertook with Canadians to arrive at this point. Part Four demonstrates our accountability in meeting the spirit and intent of our founding legislation. The document concludes with a statement from our Advisory Council.

We have proposed a responsible path forward that intends to assure rigorous standards of safety and security for people and the environment. It embraces the precautionary principle. It is grounded in concepts of continuous learning and adaptive management. We believe this is the strongest possible foundation for managing the risks and uncertainties that are inherent in the very long time-frames over which used nuclear fuel must be managed with care.

In a fundamental way our proposal advances a collaborative process in which citizens continue to play a legitimate role in making decisions, while at the same time creating conditions for productive movement forward. The nature of the waste, the inevitable uncertainties about performance years into the future, and the care that will be required over many generations, strongly suggest an ethical approach that integrates a continuing understanding of values.

As always, we take inspiration from those many individuals who have shared their views and perspectives. We count on your continued vigilance and involvement.

We particularly want to acknowledge the guidance that we have derived from the work of the Seaborn Panel in pointing to the imperative to consider the ethical and social domains as well as the technical questions on one of the approaches under review. The informal and continuing advice from Justice Thomas Berger, former Commissioner of the Mackenzie Valley Pipeline Inquiry, Dr. Hans Blix, former Director General of the International Atomic Energy Agency and Dr. Gustave Speth, Dean of the School of Forestry and Environmental Studies at Yale University, has provided important critique and validation.

We know enough to take the first steps. We also know that we must do so with caution and flexibility to allow for new knowledge and societal change over time. We are convinced that it is now time to act decisively.

Elizabeth Dowdeswell, President
May 2005

PART ONE   A Responsible Path

CHAPTER 1 / A RESPONSIBLE PATH

1.1 / Introduction

For decades Canadians have been using electricity generated by nuclear power reactors. When used nuclear fuel is removed from a reactor, that fuel is highly radioactive and requires proper shielding and careful handling to protect humans and the environment. Although the radioactivity decreases with time, used fuel will remain a potential health risk for a very long period, likely hundreds of thousands of years or longer.

The used fuel is now safely stored on an interim basis at licensed facilities at the reactor sites located in Ontario, Québec and New Brunswick. There are also small amounts at several nuclear research facilities throughout Canada. We currently have about two million used fuel bundles, and we expect to have about 3.7 million bundles if all of the nuclear reactors have an average operating life of 40 years. However, like many other countries with a nuclear power program, Canada has yet to agree on what to do with the radioactive used fuel over the long term.

In 2002, as required by federal legislation, the Nuclear Waste Management Organization (NWMO) was created. Our immediate task was to research, consult widely and make recommendations to the federal government about an appropriate long-term management approach for used nuclear fuel. We are circulating this draft report in advance of submission to government to review and test our ideas with the interested public, including the many people who have collaborated in the study.

A description of the NWMO's mandate, the amount and location of Canada's used fuel, an explanation of the hazard from this waste and a summary of the status of programs in other countries are provided in the appendices to this report.

We begin with the conclusions.

1.2 / The Recommendation

Our recommendation for the long-term management of used nuclear fuel in Canada has as its primary objectives safety – the protection of humans and the environment – and fairness to this and future generations.

Therefore we recommend to the Government of Canada Adaptive Phased Management, a risk management approach with the following characteristics:

- Centralized containment and isolation of the used fuel in a deep geologic repository in suitable rock formations, such as the crystalline rock of the Canadian Shield or Ordovician sedimentary rock;

- Flexibility in the pace and manner of implementation through a phased decision-making process, supported by a program of continuous learning, research and development;

- Provision for an interim step in the implementation process in the form of shallow underground storage of used fuel at the central site, prior to final placement in a deep repository;

- Continuous monitoring of the used fuel to support data collection and confirmation of the safety and performance of the repository; and

- Potential for retrievability of the used fuel for an extended period, until such time as a future society makes a determination on the final closure, and the appropriate form and duration of postclosure monitoring.

The Nuclear Waste Management Organization will implement this comprehensive approach, in compliance with the *Nuclear Fuel Waste Act* (*NFWA*) of 2002, and will:

- Meet or exceed all applicable regulatory standards and requirements for protecting the health, safety and security of humans and the environment;

- Provide financial surety through funding by the nuclear energy corporations (currently Ontario Power Generation Inc., Hydro-Québec and NB Power Nuclear) and Atomic Energy of Canada Limited, according to a financial formula as required by the *NFWA*;

- Seek a willing community to host the central facilities. The site must meet the scientific and technical criteria chosen to ensure that multiple engineered and natural barriers will protect human beings, other life forms and the biosphere. Implementation of the approach will respect the social, cultural and economic aspirations of the affected communities;

- Focus site selection for the facilities on those provinces that are directly involved in the nuclear fuel cycle;

- Sustain the engagement of people and communities throughout the phased process of decision and implementation; and

- Be responsive to advances in technology, natural and social science research, Traditional Aboriginal Knowledge, and societal values and expectations.

1.3 / First Principles

Our Mission

The purpose of the NWMO is to develop collaboratively with Canadians a management approach for the long-term care of Canada's used nuclear fuel that is socially acceptable, technically sound, environmentally responsible and economically feasible.

A socially acceptable management approach is one which has emerged from a process of collaborative development with citizens. It must take into account the best available knowledge and expertise, and be responsive to the values and objectives which are most important to citizens. A solid grounding in knowledge, and a fundamental responsiveness to citizens, form the foundation for public confidence.

An environmentally responsible management approach, as it has been defined through dialogue in the NWMO study, is one in which physical, chemical and biological stresses on the environment, including cumulative effects over long periods of time, and the potential consequences of failure of any part of the containment system, are within the natural capacity of environmental processes to accept and adjust to, thus ensuring the long-term integrity of the environment.

A technically sound management approach is one which is informed by the best technical and scientific knowledge and experience available in Canada and around the world, and which is practicable given our current state of knowledge. At a minimum it must ensure: public health and safety; worker health and safety; security of nuclear materials and the facilities that manage them; and environmental integrity. As well, the approach must meet international safeguards and non-proliferation obligations.

An economically feasible management approach, as it has been defined through dialogue in the NWMO study, is one that ensures 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.

Safety

Our primary motivation is safety – to protect people and the environment from highly radioactive waste. We are not confused or conflicted about this objective and common vision. More recently a specific focus on security from harmful acts, events and situations has assumed a higher profile. We must ensure that our security systems and safeguards are compliant with Canada's nuclear non-proliferation policy and international agreements.

We do not live in a risk-free world. A technical method cannot be practically demonstrated over thousands of years prior to implementation. It can only be predicted with greater or lesser confidence. Complex mathematical calculations and numerical analyses are not likely to generate required societal confidence.

That said, we must continue to build confidence that the management of used nuclear fuel will meet or exceed rigorous safety and security goals. Scientific and technical work must be, and be perceived to be, of the highest quality. Technically, a compelling case for safety must involve multiple barriers and redundant systems that maintain their integrity over exceedingly long periods of time. Over the long term, it would be imprudent to rely on a human management system with its changing forms of institutions and governance.

The Long View

Perhaps the most significant and unique feature of this issue is the time dimension. Nuclear fuel waste remains a potential health, safety and security hazard for many thousands of years, so the relative performance of any option must look out to these geological time frames. Any decision taken today will be implemented over a number of decades, at least. Undoubtedly the program will encounter major changes in science and technology, institutions, values, political perspectives, and economic and financial considerations.

We are contemplating designing and licensing a system to last for periods longer than recorded history. Under such considerations, there could be a tendency to avoid making a decision, particularly since any decision will be controversial and politically complex. Furthermore, the technology used to store nuclear fuel waste today is safe, adequate and affordable for some period of time and there appears to be no imminent safety or environmental crisis forcing a decision.

The *NFWA* reflects the sentiments and values of Canadian society: namely that this generation of citizens which has enjoyed the benefits of nuclear energy has an obligation to begin provision for managing that waste. That is consistent with the “polluter pays” principle. Waste already exists. This generation does not want to leave as a legacy the burden of providing for and funding the management of the waste we have created. We should not bequeath hazardous wastes to future generations without also giving those generations the capability to manage the waste in a safe and secure way.

We do not know what technologies may be available to succeeding generations, or what they may choose to do with the wastes that we have generated. We also do not know what the capacity of future generations will be to take an active role in managing this waste. In the light of these uncertainties, our obligation is to give them a real choice and the opportunity to shape their own decisions while at the same time not imposing a burden which future generations may not be able to manage. This means avoiding approaches that are irreversible or overly dependent on strong institutions and embracing those that are precautionary. It means planning conservatively by setting aside the financial resources to ensure that future generations will have genuine choice. It means making a commitment to continuous learning today to assist decision making tomorrow.

What we can do is plan for the foreseeable future, act responsibly and confidently with the best science and technology in hand. What we must not do is pretend that we have all the answers for all time. A measure of humility will be essential as we move cautiously but surely, one step at a time.

Citizen Engagement

The NWMO began its study with the understanding that technical and scientific experts can help us understand the *technical adequacy* of each of the management approaches available to Canada. They can also help us understand the impacts any approach may have on the *environment*, and whether the approach is affordable (*economically feasible*). However, scientific and technical evidence and analysis, while essential, cannot be the sole basis of our choice.

The views of Canadian society in judging benefits or risks, and assessing the social implications of various approaches for long-term management, are critical to the development of a socially acceptable recommendation. Canadians expect that the best scientific and technical knowledge must be brought to bear in identifying and understanding the source and nature of risk and the ways in which safety can be assured. However, the decision as to whether safety has been assured to a sufficient degree to warrant implementation is a societal one, and will be affected by social notions of what constitutes risk, safety and thresholds to be met.

We set aside traditional notions of consultation as they have too often in the past resulted in one-way conversations. We have consistently tried to design processes of dialogue to encourage listening and learning, and genuinely engage those who are interested in this matter. We have tried to be responsive to a variety of views and perspectives. As can be seen from Part Two of this report, thousands have helped us in the search for societal direction and common ground.

Sustained engagement with people and communities, whether they welcome, oppose or seek modifications to our observations and conclusions, is vital. We recommend that the building of relationships continue as decisions are taken and implementation begins.

1.4 / The Technical Possibilities

Sound science and technology must be the starting point for any examination of alternative management approaches. For about four decades, various countries have been investigating numerous technical methods. Deep geological disposal has been the subject of intensive study in Canada, and is in an advanced state of scientific and technical understanding internationally. Storage technologies have been demonstrated at reactor sites for many years.

Our assessments have confirmed that there is reason to be confident that all three technical methods or concepts under consideration here are technically credible and could be designed to be safe for the near term. Furthermore, our regulatory regime would demand such "proof of concept" before licensing.

The word "disposal" has come to mean permanence and irretrievability in the minds of the public, and that raises questions about our stewardship of the waste. To others the word "storage" implies a temporary approach that avoids taking a decision, and places a burden on future generations. For purposes of this report we have defined storage as a method of managing the waste in a manner that allows access under controlled conditions for retrieval or future activities while disposal is conclusive without any intention of retrieval or further use.

Additional options that had at some point received international attention were reviewed and found to be lacking in meeting important criteria such as proof of concept or legality. Members of the public had a particular interest in reprocessing of used fuel, as it seemed to be related to desirable environmental concepts of recycling and reuse. Partitioning and transmutation were also of interest for the possibility of reducing the volume and toxicity of the waste to be managed. For a variety of reasons outlined in Part Four, we believe that these options are unlikely to be economic, practical or desirable in Canada at this point in time.

For each of the three specific technical methods identified in the *NFWA*, engineering design concepts and cost estimates were developed by the Joint Waste Owners: Ontario Power Generation Inc., NB Power Nuclear, Hydro-Québec and Atomic Energy of Canada Ltd. These methods are described in more detail and assessed in Parts Three and Four. A brief description of these illustrative conceptual designs follows.

Option 1: Deep Geological Disposal in the Canadian Shield

This option involves placing the wastes deep underground, relying on natural and engineered barriers to isolate the used fuel from humans and the surface environment over its hazardous lifetime. A deep geological repository would be located in the Canadian Shield at a nominal depth of 500 to 1,000 metres. Fuel would be transported from the existing interim storage facilities at nuclear reactor sites to this central site where it would be packaged in corrosion resistant containers. Over a period of about 30 years, these containers would be placed in rooms excavated deep in the rock. Performance of the repository would be monitored during placement of the used fuel after which the underground excavations would be backfilled and sealed. After closure, maintenance, inspection and security-related operations would be minimal. Such a facility would be designed to be passively safe over the long term, and not rely on institutional controls to ensure safety.

This concept was researched in depth by Atomic Energy of Canada Limited from 1978 to 1996, and reviewed by the Seaborn Panel under the *Federal Environmental Assessment and Review Process Guidelines Order* (1984). The original concept has been further developed based on underground research and experience both in Canada and internationally. It now incorporates provisions for extended monitoring as well as the technology to retrieve used fuel after placement in the repository.

Option 2: Storage at Nuclear Reactor Sites

Currently, when used nuclear fuel is removed from reactors it is placed in wet storage for about seven to ten years to reduce its heat and radioactivity. It is then transferred to containers for dry storage in a facility at the reactor site. The design life of the concrete and steel storage containers is about 50 years, although the expected life is estimated to be at least 100 years.

This option for used fuel management would involve either the expansion of existing dry storage facilities or the construction of new, long-term dry storage facilities at each of the seven storage sites in Canada. Over time, used fuel would have to be transferred from the existing interim storage facilities to newly designed storage containers and facilities at the reactor sites with various components designed to last between about 100 and 300 years. We project that storage facilities would need to be completely refurbished or replaced about every 300 years.

This option would require an indefinite cycle of replacement and refurbishing activities, as facilities would be renewed at the reactor sites. Processing buildings, which would also require ongoing maintenance, inspections and security systems, would also be needed for fuel loading and on-site transfer.

Option 3: Centralized Storage, Above or Below Ground

Centralized extended storage would involve creating new, long-term storage facilities at a central location. Conceptual designs have been developed for a storage facility built above or below ground, with options including: casks and vaults in storage buildings, surface modular vaults, casks and vaults in shallow trenches, and casks in rock caverns. The used fuel would be transported from the seven interim storage sites in Canada to this new central facility.

The various components of the storage facility would have design lives between 100 and 300 years. It is projected that the storage facility would need to be completely refurbished or replaced every 300 years or so. This option for used fuel management would require an ongoing program of regular replacement and refurbishing activities, as the facility would be renewed indefinitely at the central site. Processing buildings, which would require ongoing maintenance, inspections and security systems, would also be needed for fuel loading and on-site transfer.

The Fourth Option Evolves

In defining and evaluating the three mandated options, it became clear that each possessed some unique strengths, but also some important limitations. These options are not necessarily mutually exclusive. For example, even a timely decision to pursue development of a geological repository would require decades of continued storage before such a facility could be put in operation, followed by additional decades for complete transfer of the fuel. Or, a decision to choose long-term storage at the reactor sites would not preclude future generations from making a subsequent decision to move the fuel to some centralized location, provided funds were made available. As well, potential sites for a deep repository may be found in regions beyond the Canadian Shield in other geotechnically suitable rock formations, such as Ordovician sedimentary rock basins.

Furthermore, Canadians have expressed two complementary objectives. They are prepared to assume responsibility now for dealing with waste that has been created, but they also want to preserve the ability of future generations to do what they see as being in their best interests.

The insights from the assessments led us to search for an approach that might better meet Canadian objectives than any of the three options taken in isolation. The challenge of taking the long view demanded by this issue caused us to explore how we could build in sequential decision-making which would preserve flexibility during implementation in the coming years.

What follows is an illustrative conceptual design for such an approach – Adaptive Phased Management. A more definitive design, site selection and implementation timetable can only be developed following a federal government decision about the selected long-term management approach for Canada.

1.5 / A Fourth Option: Adaptive Phased Management

The Adaptive Phased Management approach is based on centralized containment and isolation of Canada's used nuclear fuel deep underground. The approach builds on the best features of the three approaches outlined in the *NFWA*, and implements them in a staged or phased manner over time.

There are three major phases for concept implementation, which are described below for illustration purposes. Further details on the management approach can be found in Part Four, and a technical description can be found in Appendix 3. Each of the three phases has a number of key activities and decision points. While we do not know the precise duration of these activities or the outcome of future decisions, we can provide an indication of a representative schedule for implementation based on the conceptual design work and previous analysis of the three options for used fuel management under study.

Table 1-1 Adaptive Phased Management – A Possible Path

ADAPTIVE PHASED MANAGEMENT – A Possible Path	
Concept	The three 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 **Phase 1 (approximately the first 30 years):** 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. Continue engagement with regulatory authorities to ensure pre-licensing work will be suitable for the subsequent licensing processes. 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. Initiate licensing process, which triggers the environmental assessment process under the *Canadian Environmental Assessment Act.* 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. Develop and certify transportation containers and used fuel handling capabilities. Construct the underground research laboratory at the central site. Decide whether or not to proceed with construction of shallow underground storage facility and transport of used fuel to the central site for storage during Phase 2. If a decision is made to construct shallow underground storage, obtain an operating licence for the storage facility. **Phase 2 (approximately the next 30 years):** 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. Complete the final design and safety analyses to obtain the required operating licence for the deep repository and associated surface handling facilities. There may be a need for transportation containers and facilities to produce them; processing facilities to load the fuel into transportation containers; production facilities for storage containers and; processing facilities to transfer the fuel from transportation to storage containers. **Phase 3 (beyond approximately 60 years):** 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. Engage citizens in ongoing monitoring of the facility. A future generation will decide when to close the repository, decommission the facility and the nature of any postclosure monitoring of the system. There may be a need for production facilities for used fuel containers; processing facilities to transfer the fuel from storage to deep repository; and production facilities for sealing materials.

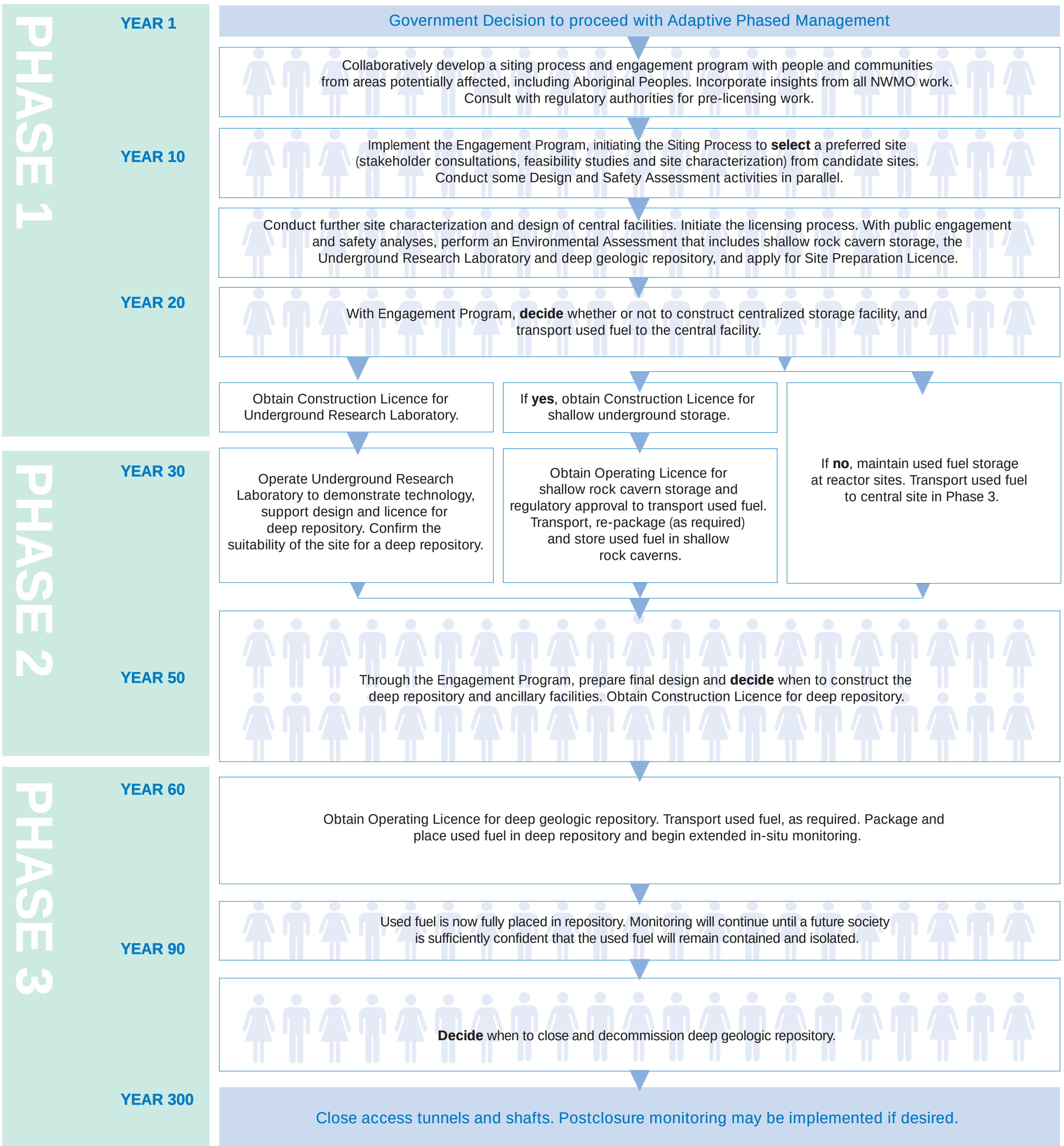
Table 1-1 (cont'd) Adaptive Phased Management – A Possible Path

ADAPTIVE PHASED MANAGEMENT A Possible Path	
Location	The central facility for the shallow rock cavern, underground research laboratory and deep repository could be located in a suitable rock formation such as the crystalline rock of the Canadian Shield or in the Ordovician sedimentary rock basins. These two rock types cover a vast amount of land reaching a significant portion of six provinces and two territories. A specific location would need to be identified, and licences would be required from the Canadian Nuclear Safety Commission (CNSC) for the siting, construction and operation of the facility. This would also require an environmental assessment.
Transportation Requirements	The operation of a central facility would involve moving the fuel from existing reactor site storage facilities in certified transport containers to the central site over a period of approximately 30 years. Transportation would require an emergency response plan and adherence to security provisions. The mode of transportation (road, rail or water) would depend on factors such as the location of the central facility. The timing of transportation would depend on whether or not a shallow underground storage facility has been constructed at the central site and other factors.
Containers	Storage containers at reactor sites would consist of the existing casks, vaults and silos. Storage containers at the central facility are based on the existing design of the dry storage container or equivalent with a 100-year design life. Facilities would exist at the central site for repackaging the used fuel. Containers for long-term isolation in a deep repository are based on a 100,000-year design life. These durable containers are designed to withstand long-term environmental effects, such as climate change and glaciation.
Underground Facilities	During the Phase 2 extended storage period, the central facility would store used fuel in a series of shallow rock caverns excavated at a nominal depth of 50 metres below surface. During the Phase 3 long-term isolation period, the central facility would place used fuel in a network of horizontal tunnels and rooms excavated in stable rock at a nominal depth of 500 to 1,000 metres below surface. Used fuel containers would be placed within the rooms or in boreholes drilled into the floor of the rooms. Used fuel containers are assumed to be placed in a deep repository over a 30-year operating period.
Repository Sealing System	Clay-based materials could be used to surround and protect the containers, to fill the void spaces in the repository, to limit the movement of groundwater and dissolved material, and to protect workers during container placement operations. These are referred to as sealing systems, and involve materials such as high-performance concrete and swelling bentonite clay.
Geosphere Barrier	The geosphere, or host rock, provides the principal barrier between the used fuel containers and the surface environment. Both the crystalline rock of the Canadian Shield and the Ordovician sedimentary rock basins are examples of naturally occurring geologic formations which have long-term stability, good rock strength, low groundwater flow, and large areas exist with sufficient depth below the surface and lacking in mineral resources such that they are very unlikely to be disturbed by erosion or accidental drilling.

Table 1-1 (cont'd) Adaptive Phased Management – A Possible Path

ADAPTIVE PHASED MANAGEMENT A Possible Path	
Monitoring and Retrievability	Used fuel would be monitored in the central shallow rock caverns and in the deep repository. During Phase 2, monitoring and retrieval would be straightforward over the 30-year period, since the storage containers would be readily accessible. During Phase 3, monitoring and retrieval over an estimated 240-year period would require more effort and technology since the long-term isolation containers would be backfilled and sealed within the placement rooms. Monitoring would be conducted to confirm the long-term safety and performance of the repository system. Until a decision was made to backfill and seal the access tunnels and shafts of the deep repository, monitoring would take place in-situ at repository depth. After closure of the deep repository around 300 years, postclosure monitoring of the facility could take place from the surface.
Implementation Schedule	A government decision in 2006 to select this management approach would see a new central shallow rock cavern storage facility and underground research laboratory ready by about 2035, and the deep geologic repository ready by about 2065. Following a decision by the federal government, the major steps in implementing this management approach include: • Siting of central facilities (about 20 years); • Design and construction of shallow underground storage caverns and underground research laboratory (about 10 years); • Transportation to central facility (over about 30 years); • Placement in deep geologic repository (over about 30 years); • Extended monitoring (out to 300 years); • Decommissioning and closure (over about 25 years); and • Postclosure monitoring (indefinite) There will be a need to obtain a licence at each phase, and demonstrate continuous compliance with the licence (under regulatory oversight).
Costs	The cost of this management approach for used nuclear fuel is conservatively estimated to be about $24 billion (2002 dollars), including interim used fuel storage and retrieval from reactor sites, transportation costs to the central facility, extended storage in underground caverns, technology research development and demonstration in the underground research laboratory and placement of used fuel in a deep geologic repository. These costs include the development and demonstration of the technology to retrieve used fuel from the deep repository, but not the costs to perform retrieval operations from the deep repository. The present value cost based on current long-term economic factors is approximately $6.1 billion (2004 dollars). (www.nwmo.ca/assessments) These costs include construction and operation of the shallow underground storage facility at the central site. If, however, the used fuel remains at the reactor site prior to operation of the deep repository and is not first placed in shallow storage, these costs would be reduced to about $22 billion (2002 dollars) with a present value of about $5.1 billion (2004 dollars).

Figure 1-1 Activity Flow Chart for Adaptive Phased Management



Assessment Findings

As required in the *NFWA*, we have undertaken a comparison of the benefits, risks and costs of each management approach with those of the other approaches, taking into account the economic region in which that approach might be implemented, as well as ethical, social and economic considerations associated with that approach.

The framework for this comparison emerged from dialogue with citizens over the course of our study. It was designed to capture the objectives that those Canadians who participated in the study believed were important in assessing the appropriateness of any management approach for used nuclear fuel for Canada. The key objectives are: fairness; public health and safety; worker health and safety; community well-being; security; environmental integrity; economic viability; and adaptability. The comparison was also intended, as much as possible, to be responsive to the values and ethical principles which citizens suggested should drive decision-making.

We reached our conclusions through an iterative process of several stages. Our analysis suggests:

- Taken individually, no one of the management approaches specified in the *NFWA* perfectly addresses all of the objectives which citizens said were important for any management approach for Canada to address, particularly when both the near term (the next 175 years) and the longer term are considered;

- Each of the three approaches has distinct advantages and limitations in light of this framework;

- A management approach which incorporates the most significant advantages of each approach, supported by a phased decision-making process designed to actively and collaboratively manage risk and uncertainties, is expected to perform better on our objectives than the other three approaches; and

- The process of implementation will be a test of the degree to which any of the approaches would ultimately address citizen objectives, values and ethical principles. Therefore, the requirements for an implementation plan form an essential part of our recommendation.

The storage options, Option 2: Storage at Nuclear Reactor Sites and Option 3: Centralized Storage, are expected to perform well over the near term (at least within the next 175 years). However, the existing sites were not chosen for their technical suitability as permanent storage sites. Furthermore, the communities hosting the nuclear reactors have an expectation that the used nuclear fuel will eventually be moved.

The NWMO believes that the risks and uncertainties concerning the performance of these storage approaches over the very long term are substantial in the areas of public health and safety, environmental integrity, security, economic viability and fairness. A key contributing factor in this expected performance is the extent to which the storage approaches rely upon strong institutions and active management to ensure the safe and effective performance of the management system. The NWMO expects that these institutions and the capacity for active management will be strong over the foreseeable future, but uncertain over the very long term. The NWMO believes that the type of responsible and prudent approach that Canadians have suggested is required dictates that we not rely upon the existence of strong institutions and active management capacity over thousands and tens of thousands of years. On this basis, the NWMO does not suggest either of the storage options as a preferred approach for the long term.

Deep Geological Disposal in the Canadian Shield, Option 1, is judged to perform well against the objectives in the very long term because of the combination of engineered and natural barriers to isolate the used fuel. A key weakness, however, is its lack of adaptability, which is an important objective in the minds of citizens. Over the short term, the approach is judged to be less flexible in responding to changing knowledge or circumstances either concerning the performance of the system itself over time, or more broadly to innovations in waste management technologies. There is some uncertainty about how the system will perform over the very long term because we cannot obtain advance proof of the actual performance of the system over thousands of years. Also, this approach provides comparatively little opportunity for future generations to influence the way in which the used fuel is managed. Its lack of adaptability is a weakness that may ultimately affect the performance of the system over time on the other objectives such as public health and safety and environmental integrity.

Adaptive Phased Management, Option 4, has been designed to build upon the advantages of each of the three approaches studied and includes as an important element an adaptive and phased approach to implementation, which is designed to reduce the uncertainties at each phase in the process and over time. Involvement of citizens in decision-making throughout all of the phases is important. The NWMO considers Option 4 to offer a preferred approach.

- This approach is designed to be highly adaptive in the near term, the period in which it is reasonable to believe there will be strong oversight institutions and active management capacity. It entrenches an explicit and planned process of social learning and action. Over this period, new learning and technological innovation is easily incorporated into the management plan. Some social uncertainties, such as the role of nuclear generation in the energy mix in Canada's near future, may be resolved. Some technical uncertainties, such as whether evolving technologies (i.e. transmutation) will become practicable, are also likely to be reduced. Some uncertainties over the performance of aspects of the deep geological system are also expected to be reduced with further research, testing and experimentation, particularly at the location where such a facility might be sited;

- This approach clearly identifies the technology associated with a deep geologic repository as the appropriate end point. It does not rely upon human institutions and active management for its safe performance over the long term. The approach plans for and puts in place a safe and secure containment option for the used nuclear fuel at each point in the process. It provides real options and contingency plans should implementation through the phases not proceed as planned. In particular it provides the option of more robust and secure interim storage in shallow underground caverns located centrally at the site of the deep repository;

- This approach provides opportunity for future generations (at least over the next 300 years) to influence the way in which the fuel is managed;

- This approach provides for research and collaborative decision-making in the determination of the manner and timing of movement through the phases; and

- This approach suggests a process through which confidence in the technology and supporting systems can be developed before moving to the final phase.

Finally, our analysis suggests that some important issues are not fully addressed through the selection of the management approach itself. They will need to be considered through the collaborative decision-making process, which should accompany the implementation of any approach. These issues include the design of a fair siting process and the determination of safety thresholds that would need to be met before moving through each phase of implementation.

1.6 / Implementation

Any management approach, no matter how well conceived, will fail if it is not also well executed. The process by which a management approach is implemented, and the institutions and systems which are put in place, will be important determinants of the overall effectiveness of the approach and the extent to which it is and continues to be responsive to societal needs and concerns.

Governance and Institutions

Canada has an extensive system of governance to oversee the long-term management of used nuclear fuel. This governance framework involves many players including governmental and regulatory agencies, the waste owners, the community hosting the facility and the NWMO, all of whom will participate in the ongoing decisions, implementation and operations. Specific roles and responsibilities are outlined in Part Four.

After a decision is made by the Government of Canada, the NWMO will become the implementing agency. It will be directed and governed by the provisions of the *NFWA*, and subject to a number of federal, provincial and international acts and regulations. In addition to the federal government, provincial governments, Aboriginal Peoples and host communities will also play important roles when a management approach is chosen.

The Canadian Nuclear Safety Commission (CNSC) is responsible for regulating the use of nuclear energy and nuclear materials to protect the health, safety, and security of Canadians, to protect the environment, and to ensure that Canada's commitments on the peaceful use of nuclear energy are respected. Canada's regulatory framework will provide for the safe, secure construction and operation of the facilities and transportation of the used nuclear fuel, demanding that standards are met or exceeded.

The NWMO will be required to apply to the CNSC for licences to prepare a site, construct, operate, modify, decommission and where appropriate abandon a nuclear fuel waste management facility. For centralized options, the NWMO will also be required to obtain a licence to transport waste fuel. In operating a nuclear waste repository, the NWMO will be required to demonstrate at regular intervals that it is meeting all applicable regulations. The necessary decommissioning plan forms the basis for the financial guarantee, which is required to ensure that funds will be available to implement the decommissioning plan and to avoid placing any financial burden on future generations.

The CNSC is defined as a federal authority under the *Canadian Environmental Assessment Act* (*CEAA*) and as such must ensure the requirements of the Act are met before it can proceed to licensing under the *Nuclear Safety and Control Act* (*NSCA*). Appendix 11 provides more detail on the Canadian regulatory framework relevant to the management of used nuclear fuel, including transport.

As required by the *NFWA*, Canada's three nuclear energy corporations, Ontario Power Generation Inc., NB Power Nuclear and Hydro-Québec, established the NWMO in 2002. It is under the governance of the Board of Directors that the NWMO will carry out the managerial, financial and operational activities to implement the long-term management of nuclear fuel waste. The three member corporations confirmed the objectives of the NWMO and clarified the roles and responsibilities of the member corporations in furthering those objectives. This includes provisions for cost-sharing the NWMO's annual operating budget up to an annual maximum.

The legislation also required the NWMO's governing body to appoint an Advisory Council, and provided specific direction on its membership and responsibilities. The Advisory Council has an ongoing responsibility to examine and to provide written comments on the triennial reports that the NWMO must submit to the Minister of Natural Resources Canada. As set out in our legislation, council membership will change over time as the project proceeds from a study on management options, to a concept chosen by government, and then, to a site-specific project in a known location and region. Once an economic region has been identified for implementing the approach selected by the government, representatives nominated by those local and regional governments and Aboriginal organizations will be added to the Council.

Canada's four waste owners, currently Ontario Power Generation Inc., NB Power Nuclear, Hydro-Québec and Atomic Energy of Canada Limited, are responsible for establishing trust funds to finance the implementation of the management approach selected by government.

Implementation Plans

Implementation plans *cannot* be designed by the NWMO in detail at this time. Nor should they.

- Plans must be specified with the many communities of interest who will have important roles to play in overseeing and participating in implementation following a government decision on an approach. We expect to hear a diversity of voices as we seek advice and receive direction on the design of the process and the issues to be explored;

- Implementation plans will not be static. They must continue to evolve. The unprecedented time horizon brings with it a need for continuous learning, and a commitment to collaboratively define and periodically assess indicators of progress as a means of facilitating adaptation to evolving conditions; and

- Similarly, timetables for implementation cannot be proposed in specific terms at this time. They must be discussed and defined as part of the necessary collaboration and dialogue that will take place as the NWMO prepares to implement government's decision.

Financing

Ensuring financial surety for the approach means determining what costs can reasonably be expected to occur over the life of a project, along with some contingency for unexpected events. We will design a system that collects and protects enough funding to ensure that the entire cost of the project can be covered under a variety of social and economic circumstances and within the required time-frame.

Canada has a robust system of legal and regulatory oversight, covering all aspects of the nuclear industry. The standards that have been developed to provide financial surety for the long-term management of spent nuclear fuel share many elements of design and implementation with other nations around the world. Financial guarantees have been required by the CNSC, and may be required in future. These have been provided by all waste owners but to this point have not been harmonized. Details are provided in Part Four.

The following financial details are addressed in legislation and regulations:

- Methods for collecting and managing funds that will meet the cost estimate forecasts in an equitable manner and within reasonable time-frames;

- Methods for adjusting the rate and size of funds that are collected should circumstances change over time;

- Reasonable determinations of cost estimates, derived financial obligations and forms of financial surety provided;

- Contingency programs that will allow all financial obligations to be met even when unexpected events significantly affect the Canadian market;

- A reporting methodology to verify that appropriate financial practices are implemented and that on-going adjustments are made to both cost estimates and the financial guarantees to ensure they are accurate; and

- Setting limits on liability and insurance requirements for various licensed operations.

The *NFWA* sets out requirements for the establishment of trust funds for the long-term management of Canada's used nuclear fuel. Trust fund contributions made by each producer will be reviewed as part of the annual report, with comprehensive reviews conducted every five years. Contributions will be continually adjusted to reflect improved projections of overall costs and number of fuel bundles to be produced by each waste owner.

Each waste owner has established an individual trust fund that is held and managed by an independent financial institution. As specified by the *NFWA*, deposits continue to be made by all four bodies, currently totalling $770 million. Experience in other countries has demonstrated the importance of safeguarding these large funds, so that they will be preserved for the intended purpose. In Canada, the legislation built in explicit provisions that will ensure that these trust funds are maintained securely and used only for the intended purpose.

A funding formula has been developed to set out the respective percentage of the estimated total cost of management of nuclear fuel waste that is to be paid by each nuclear energy corporation and Atomic Energy of Canada Limited, along with an explanation of how those respective percentages were determined. For all options involving a centralized facility, the overall objective is to share actual costs of long-term management based on the number of fuel bundles. That is, each waste owner would pay the same costs for each fuel bundle subject only to owner-specific costs such as transportation. For storage at nuclear reactor sites, costs would be borne by the waste owner at each specific site. For shared facilities at a given location, costs would be shared based on waste fuel quantities at that location.

The NWMO will have an ongoing obligation to assess the accuracy of the cost estimate for the selected management approach, and the sufficiency of contributions to cover cash flow obligations for the life of the project.

Economic Regions and Siting

The legislation directed us to propose economic regions suitable for implementation for each approach. According to Statistics Canada, there are 76 economic regions, broad-based geographic units based on census divisions, which are used for compiling statistics and analysis of regional economic activity.

We believe that fairness would best be achieved if the site selection process is focused within the provinces that are directly involved in the nuclear fuel cycle. Accordingly, in specifying economic regions, for centralized options we have proposed that the focus of the site selection process be in the three provinces that generate electricity from nuclear power, and consequently create used nuclear fuel a by-product (Ontario, New Brunswick and Québec), as well as Saskatchewan, which has benefited economically from the mining of uranium that is used to make our nuclear fuel. We believe that these provinces have a greater responsibility than do other provinces and territories to manage the waste stream arising from the nuclear process. We recognize that communities in other regions and provinces may come forward with interest in possibly hosting the facility. Such expressions of interest should also be considered.

Our analysis showed that there is great diversity of demographic, socio-economic and biophysical characteristics within any given region. In fact there is often as much variation within an economic region as between regions, making it difficult to generalize about the suitability of one region over another.

The boundaries of those economic regions are not meaningful for the purpose of engaging discussion around possible host communities. They do not reflect political or legal boundaries or those of traditional Aboriginal territories or our country's ecozones. We concluded that they could not be used as a basis to narrow the scope of possible regions for implementation at this time. Ultimately, decisions on locating a facility will be made on site specific characteristics.

It is our intention to seek a willing host community for any facility that may be required. In order for a site to be acceptable, it would need to address scientific and technical siting factors to ensure that any facility built is capable of protecting us and future generations, other life-forms and the biosphere as a whole into the indefinite future.

We propose that the siting process be designed to:

- Be open, inclusive and fair to all parties, giving everyone with an interest in the matter an opportunity to have their views heard and taken into account;
- Ensure that groups most likely to be affected by the facility and associated transportation are given full opportunity to have their views heard and taken into account, and that they are provided with the forms of assistance they require to present their case effectively;
- Include special attention to Aboriginal communities that may be affected;

- Be free from conflict of interest, personal gain, or bias among those making the decision and/or formulating recommendations;

- Be informed by the best knowledge – in particular the best natural science, the best social science, the best Aboriginal knowledge, and ethics – relevant to making a decision and/or formulating a recommendation;

- Be in accord with the precautionary approach, which first seeks to avoid harm and risk of harm. If harm or risk of harm is unavoidable, place the burden of proving that the harm or risk is ethically justified on those making the decision to impose it;

- Ensure, in accordance with the doctrine of informed consent, that those who could be exposed to harm or risk of harm (or other losses or limitations) are fully consulted and are willing to accept what is proposed for them;

- Take into consideration, in so far as it is possible to do so, the benefits, costs, and risks, of the siting decision, including their physical, biological, social, cultural, and ethical aspects; and

- Ensure that those who benefit most from nuclear power (past, present and perhaps future) are bearing the costs and risks of managing spent fuel and other nuclear materials.

These issues are discussed in greater detail in Part Four.

Environmental assessment and licensing procedures overseen by the Canadian Nuclear Safety Commission and other federal agencies will demand that the safety case for the site and any associated transportation system be clearly demonstrated. For any management approach adopted, specific siting requirements will be defined once a decision has been taken on a particular approach, and the project specifications fully described.

Mitigation

We must recognize and support a host community's vision for its social, cultural and economic aspirations. It will be important to design implementation in such a way as to avoid or minimize disruptive impacts on communities, and foster positive sustained change for them. Where adverse impacts cannot be avoided, implementation must recognize the contributions and costs borne by the community through appropriately designed mitigation measures. As discussed in Part Four, a wide variety of measures are available.

The long process of designing, building and operating a used nuclear fuel management facility can serve as a bridge to the kind of future that is sought by a community, but only if the NWMO makes the decisions about implementation in collaboration with the community.

Citizen Engagement

Our study has begun a process of public engagement that should continue through the decision making and implementation stages. A continuum of engagement activities will be needed to support the decisions being taken at each step. We must communicate a clear decision-making path with accountabilities. Implementation must involve the identification and adoption of roles and responsibilities within government and industry. We must provide assurance that commitments made will be met, and that contingency plans are known and available should they be required.

Engagement will need to become increasingly a local dialogue. We must understand concerns of regions and communities that are affected directly and indirectly. These communities will become active players and problem solvers. Communities must be informed and equipped to participate in discussions and decision-making. Their participation must be based on an understanding of potential risks and the means to manage them, including those from transportation. Communities in the vicinity of any future facility must have opportunities for genuine involvement. They should be informed of issues and participate in decision-making, as well as monitoring. Effective engagement is based on principles of openness, transparency, integrity and mutual respect and involves a shared responsibility.

We will build on the relationships that we have established. Through a diverse engagement program we have sought to come to know and develop an ongoing dialogue with many communities of interest. This has laid the foundation for a longer-term relationship that will be essential as Canada moves through the phases of decision-making and implementation. The dialogue we have begun will continue and grow in the years to come. Our engagement with the Canadian public and with Aboriginal Peoples is just beginning.

Research and Intellectual Capability

We see continuous learning and adaptability as integral to successful implementation plans. A program that will evolve over a long period of time will have many opportunities for improvements to increase performance, enhance effectiveness, improve understanding, and address societal concerns. However, to realize these benefits, there needs to be a vibrant and robust research and development effort during management program development and execution.

While the role for research and issues of intellectual capacity were not explicitly required as part of our study, we believe that there are many important reasons to pursue such a research and development program that can guide the program's scope and content, including:

- Enhanced scientific understanding to improve confidence in predictions, reduce uncertainties, and to evaluate potential program improvements;
- The ability to confirm performance during and after program operations;
- The obligation to citizens to clearly demonstrate an ongoing capability to manage the enterprise and to respond to their concerns and desires;
- The ability to make mid-course corrections in response to new information or societal decisions;
- Preparation for facility siting, design, licensing, development, and operations; and
- Assurance of adequate human capacity to manage the program throughout its existence.

In Part Four we provide examples of some of the areas of research that we believe would be appropriate under any of the four management approaches and comment upon the type of expertise and capabilities that will be required. It is important to note that beyond the required technical expertise, additional research and development should be conducted on a range of non-technical issues of importance as well, including socio-economics, stakeholder involvement, and public attitudes. It would be important to involve external parties in identifying research of relevance and interest. The research work should most often be competitively determined and the work carefully peer reviewed. Finally, much work can be done in collaboration with other countries and international organizations.

1.7 / Concluding Thoughts

The observations made and conclusions reached in this report have evolved from synthesizing the views and aspirations of people, and rigorously examining technical and engineering information. There is a vast amount of accumulated knowledge. What shaped our thinking was a focus on the time dimension of the issue and the pre-eminent requirement of ensuring safety and security for people and the environment. We were concerned about fairness in the distribution of costs, benefits and responsibilities within and across generations. We were guided by a mission statement that calls for consideration of social acceptability, environmental responsibility, technical soundness and economic feasibility. We tried as openly and honestly as we could to engage citizens in defining the questions and debating the possibilities.

Our report would be incomplete if we did not refer to the impassioned arguments we heard about energy policy and the future of nuclear power.

For some it was a technical matter. Knowing the volume and type of waste might be a key element in the choice of technical option. They wanted to make sure that the options were tested against a variety of scenarios ranging from early phase-out to expansion of nuclear power. They sought assurance that an option chosen today would be robust enough to meet the needs of tomorrow, whatever those needs might be. Furthermore, in the choice of options to consider, some felt that source reduction and elimination should be a first step in any waste management program.

There were suggestions to assess the full life cycle of nuclear materials, from mining through to the management of all forms of waste. Some proposed that such an analysis would show that nuclear energy improves the quality of life and may lead to an overall reduction of stress on the environment. Others suspect that if the real costs and benefits of the full lifecycle were examined nuclear energy generation would be abandoned.

There were some who argued that from a social and ethical perspective it was important to frame the issue very broadly. They wanted to examine the very activity that gives rise to the waste in the first place. While some worried that the identification of a long-term management approach would serve as a de facto licence for the expansion of nuclear energy without adequate public discussion, others acknowledged that it was important for the current economic viability of the industry that decisions be taken.

In this report, the NWMO has not examined nor is it making a judgment about the appropriate role of nuclear power generation in Canada. We suggest that those future decisions should be the subject of their own assessment and public process.

Used fuel exists today and may continue to be produced to the end of the lives of Canada's existing nuclear facilities. The focus of our study was to recommend a responsible path forward for addressing the used fuel that requires management for the long-term. Our study process and evaluation of options was intended neither to promote nor penalize Canada's decisions regarding the future of nuclear power.

Our vision is that Canada will take responsibility for the long-term management of its nuclear fuel waste. Our recommendation proposes a path to achieve that goal through a risk management approach of deliberate stages and periodic decision points.

- It commits this generation of Canadians to take the first steps now to manage the used nuclear fuel we have created;
- It will meet rigorous safety and security standards through its design and process;
- It allows sequential decision-making, providing the flexibility to adapt to experience and societal change;
- It provides genuine choice by taking a financially conservative approach, and providing for capacity to be transferred from one generation to the next;
- It promotes continuous learning, allowing for improvements in operations and design that would enhance performance and reduce uncertainties;
- It provides a viable, safe and secure long-term storage capability, with the potential for retrievability of waste, which can be exercised until future generations have confidence to close the facility; and

- It is rooted in values and ethics, and engages citizens allowing for societal judgments as to whether there is sufficient certainty to proceed with each following step.

We believe that our approach is both responsive and responsible. It is responsive to what we understand to be the values and expectations of Canadians in providing safe and secure isolation of the waste for the very long term. It has also brought to bear the knowledge, expertise and wisdom of a variety of expert communities to help us understand the choices. We are resolute in our belief that the knowledge we have today is more than adequate to start down this path, yet humble enough to acknowledge that the future will unfold in ways that may redirect the path to our end goal.

There is no single formula or lens through which to approach this public policy challenge. It demands the wisdom of Aboriginal Elders, the expertise of natural and social scientists and engineers and the informed interest of citizens. With this draft report, the dialogue must continue. We invite your comment upon our proposals and your participation as we refine our report for final submission.

PART TWO What Canadians Said

CHAPTER 2 / HOW WE APPROACHED CANADIANS

We took as our mission "to develop collaboratively with Canadians a management approach for the long-term care of Canada's used nuclear fuel that is socially acceptable, technically sound, environmentally responsible and economically feasible." This mission is reflected in how we have approached the engagement of Canadians in our study, both in the way we asked for input and then used that input to shape the study.

We began our study with the understanding that technical and scientific experts can help us understand the technical adequacy of each of the management approaches available to Canada. They can also help us understand the impacts any approach may have on the environment, and whether this approach is affordable (economically feasible). However, we understand that it is necessary to move beyond technical and scientific experts to include the voices of a much wider range of citizens in order to judge the fourth element of our mission, social acceptability.

Scientific and technical evidence and analysis, while essential, will not be the sole basis of our decision-making. The views of Canadian society, in judging benefits or risks, and assessing the social implications of various approaches for long-term management, are critical to the development of a socially acceptable recommendation. Canadians expect that the best scientific and technical knowledge must be brought to bear in identifying and understanding the source and nature of risk and the ways in which safety can be assured. However, the decision as to whether safety has been assured to a sufficient degree to warrant implementation is a societal one, and will be affected by social notions of what constitutes risk and safety and thresholds to be met.

We expect the management approach that may be regarded by Canadians as socially acceptable will be the one which factors in the best scientific and technical knowledge available, and is most responsive to the key values and objectives articulated by citizens who participated in our process of collaborative development. This process of working collaboratively with citizens to develop a management approach for Canada is designed to ensure that not only the best scientific and technical knowledge is brought to the study, but also the values and objectives of citizens are identified and understood, and form the road map for both the study and recommendation. In doing so, we are attempting to use the social and ethical considerations expressed by citizens as a fundamental building block for the study.

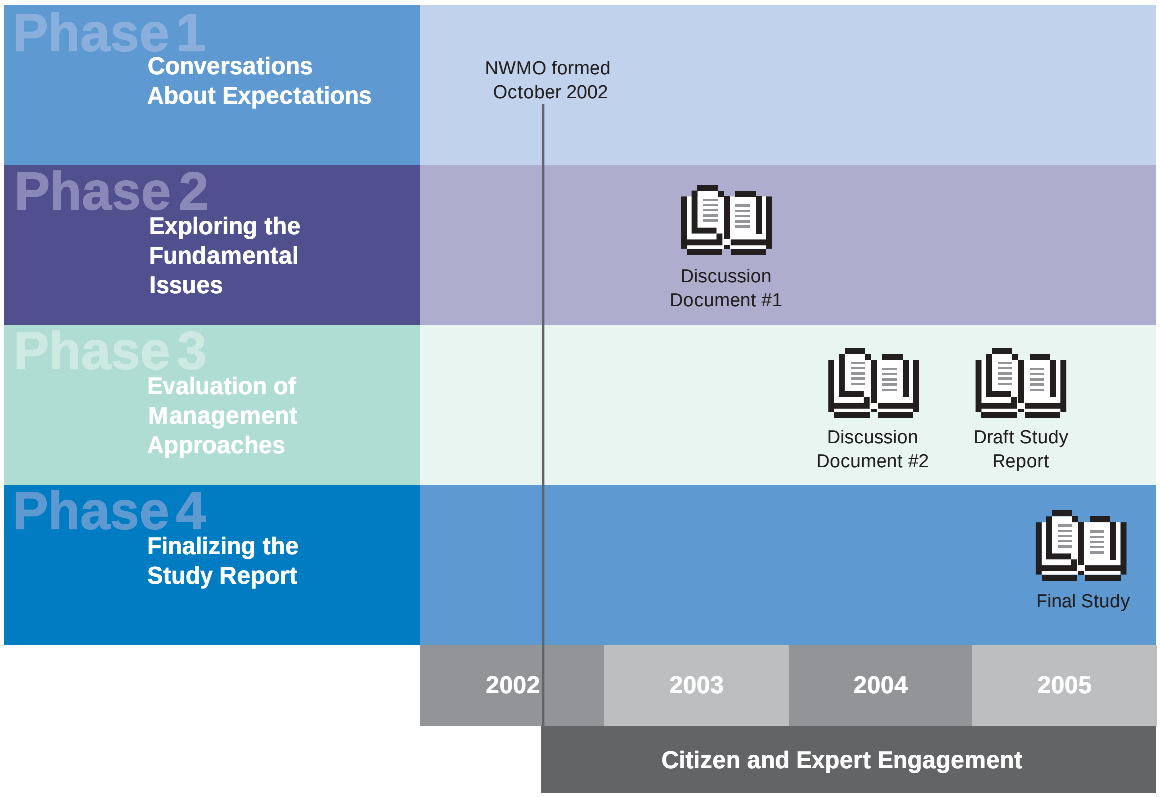
At its simplest, our study process involved asking Canadians for the list of values and objectives against which a management approach should be assessed, and then engaging Canadians in a dialogue to assess the approaches against that list. The study has been designed so that the approach which emerges as most responsive to these values and objectives will be judged the most socially acceptable of the options studied.

In this collaborative development process, our role has been to act as a facilitator of dialogue in an open forum where, as much as possible, all interested Canadians have access to information and the opportunity to put forward their views. The study process is designed in such a way that as many perspectives as possible are considered and used to shape each major decision point in the study.

2.1 / A Responsive Study Process

We designed our three-year study as a dialogue conducted over four phases: Conversations About Expectations; Exploring the Fundamental Issues; Evaluating Management Approaches; and, Finalizing the Study Report. Each of these four phases focused on a key decision point for the study, for which the direction of Canadians is elicited through dialogue, before proceeding to the next key decision point and phase of work. The four phases were supported by a series of milestone documents, designed to share what we have heard from Canadians, how this has shaped our thinking, and to elicit public feedback to shape and direct subsequent steps in the study. Through these documents, we have sought to make transparent our deliberations, to "think out loud," and to elicit comments and direction to help shape each key decision in the study.

Figure 2-1 NWMO Study Plan



The dialogue process sought direction from Canadians at each of the following points:

- Identifying the questions to be asked and answered in the study, and the key issues to be addressed in the assessment of the management approaches;
- Confirming the range of technical methods to be considered in the NWMO study;
- Assessing the risk, costs and benefits of each management approach through the assessment process; and
- Designing the overarching management structure and implementation plans for each management approach considered in the study.

For this public policy issue, we understand that all Canadians may have an interest. We learned early on, from public attitude research, that the public attaches high importance to this issue, once it is brought to their attention, and expects to play an important role in the study. However, we also learned that most have little knowledge about the issue, and little interest in becoming personally involved in the study. Recognizing that many members of the public will not involve themselves in the discussion of this issue, although the inclusion of public input is considered key to a credible study process by the public, we have tried to deliberately include a diversity of voices. In this way we are attempting to ensure that a broad range of social and ethical considerations are raised for consideration in the study.

We have sought this societal direction in part through a dialogue with citizens about the values and objectives that ought to drive decision-making on a waste management approach and the concerns that will need to be addressed. We have also sought this societal direction through a dialogue with experts focused on understanding the current state of scientific knowledge related to the long-term management of used nuclear fuel, and the practicable options which are available to meet the values and objectives which citizens judge to be important.

Over the course of the dialogue, a broad range of engagement and dialogue techniques have been used, including traditional and more innovative approaches. In order to elicit the range of social and ethical considerations which citizens bring to bear on this issue, we have used nation-wide surveys, focus groups, issue focused workshops and roundtables, e-dialogues and deliberative surveys, and public information and discussion sessions.

Some of these techniques have been used to ensure that we have heard from a statistically representative cross-section of citizens, including those who would not otherwise involve themselves in the study. Some of these techniques have been used to elicit the concerns of those who are directly interested in the issue. Some techniques have been used for more in-depth conversation among those with a specialized interest. Throughout, our website has served as a platform, not only for making publicly available all reports commissioned by the NWMO, but also to share what was said and inviting submissions and comment from Canadians on any of these topics. Each dialogue initiative has been conducted, and reported on, by third parties in order to ensure the accuracy and transparency of the reporting.

In order to explore the state of scientific knowledge (both natural science and social science) related to the long term management of used nuclear fuel, and the practicable options from which to choose, we commissioned a series of background papers, each prepared by an expert in that field and peer reviewed. Experts also prepared illustrative conceptual engineering designs, and cost estimates, for each of the short listed options in the study. These conceptual designs formed the basis for much of the broader public discussion, especially in the latter part of the study.

Among the dialogue initiatives undertaken to date are:

- A scenarios exercise. To explore the possible repercussions for future generations of decisions we make today, we worked with Global Business Network to bring together a group of individuals drawn from many interests. The group was asked to identify a range of plausible futures and conditions that might need to be faced in managing used nuclear fuel over the long term;

- Commissioned papers. Canadian and international experts were commissioned to provide up-to-date information on the current state of knowledge on issues related to the long-term management of used nuclear fuel. These included the status of biospheric and geospheric research, lessons learned from other experiences in hazardous waste management, financing considerations, and various aspects of our legal and administrative framework. Experts were also asked to explore how concepts such as adaptability, sustainable development, risk and uncertainty, security and the precautionary approach might apply to the study;

- A workshop with technical and scientific specialists from a wide range of fields. We worked with McMaster University to convene a workshop to explore the technological requirements to allow for: flexibility in decision-making; extended monitoring; retrievability; larger or smaller volumes of waste; different types of used nuclear fuel; and the development of new technologies and/or breakthroughs;

- A national citizens dialogue on values. To explore the values which citizens bring to bear in thinking about the long-term management of used nuclear fuel, we worked with the Canadian Policy Research Networks to involve a cross-section of citizens across Canada in day-long deliberative dialogue sessions. From this emerged a short list of priorities or “values” to drive decision-making on this issue. The appropriateness of these values was subsequently confirmed through further dialogue with Canadians and so became an important element of the framework used to assess approaches.

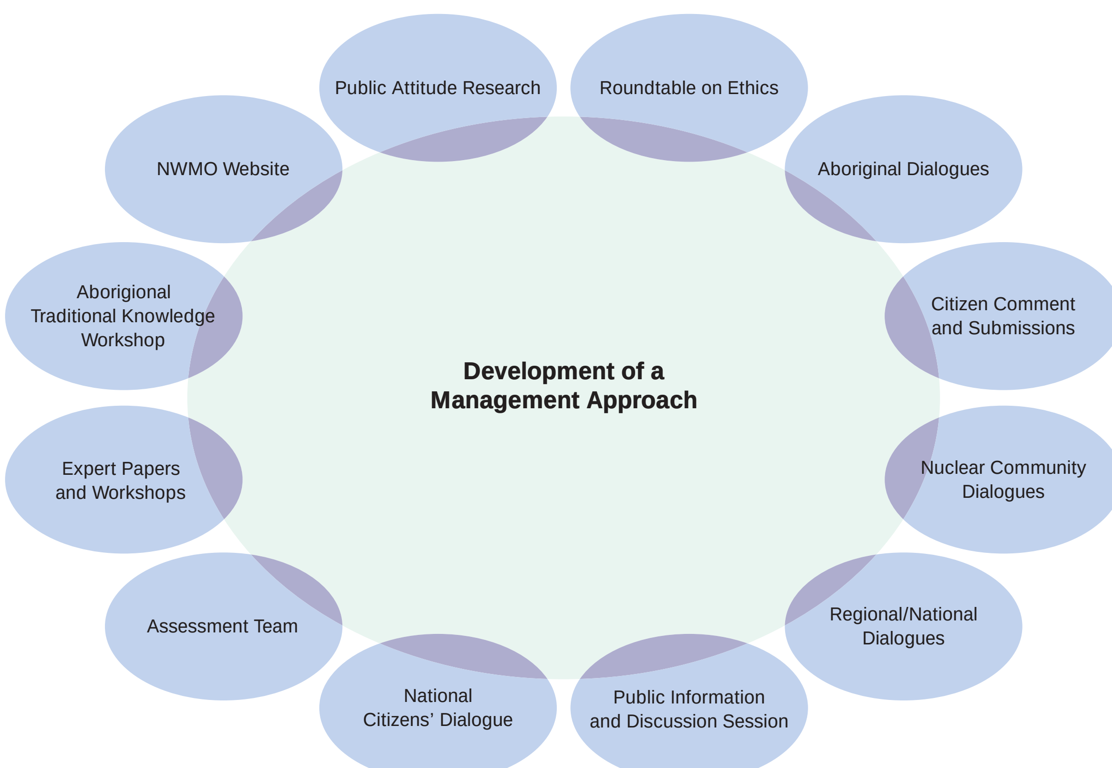
- Public information and discussion sessions. In conjunction with an independent consulting firm, DPRA Canada, a series of 120 public information and discussion sessions were convened in 34 locations across Canada. These sessions were designed to share highlights of our study to date, and hear comments from interested Canadians;

- Dialogues designed and conducted by Aboriginal Peoples. Early on in the study, we began discussions with national Aboriginal organizations to design and implement their own dialogue process as a means of providing input to the study. Subsequently, the program expanded to include local and regional organizations. Culturally specific material has been created, and dialogues have occurred in languages such as Inuktitut, Ojibway, Michif and Cree. Aboriginal Peoples have also participated in and contributed to many of our other dialogue initiatives designed to solicit input from a diversity of experts and citizens;

- A roundtable of experts on ethics. The Roundtable on Ethics was established to deliberate on the range of ethical considerations that should be factored in to the study. Among the early advice we received was that rather than treating ethics as a separate and distinct assessment area, it would be preferable to embed ethical and value considerations in all aspects of the study. This echoed advice of the participants in the Aboriginal Traditional Knowledge Workshop we convened early in the study. The Roundtable developed an Ethical and Social Framework, reproduced in Appendix 6, composed of principles and questions to help guide our activities. These principles also became an important part of our assessment framework;

- A roundtable session with public opinion leaders in the communities that currently host used nuclear fuel interim management facilities. With the assistance of expert facilitators from Simon Fraser University, we brought together for the first time opinion leaders and other representatives from each of the current host communities to discuss how these communities might best be engaged in the study process; and

Figure 2-2 Development of a Management Approach
The NWMO has attempted to use a wide variety of techniques to bring a diversity of voices to the study.



- E-dialogues. A series of e-dialogues was conducted, in conjunction with Royal Roads University, to explore issues of risk and uncertainty associated with the long-term management of used nuclear fuel.

The process through which we sought to elicit societal direction at each major step along the way, is designed to be responsive to what Canadians told us about what an appropriate study process should embody:

- The study process must be grounded in knowledge and expertise;
- The study must solicit and consider a wide range of perspectives;
- The NWMO should "think out loud" and engage citizens in dialogue at multiple points in the process;
- The process must be fair, transparent and trustworthy;
- The process must make information accessible to members of the public who currently know little about this issue; and
- The process must use a variety of methods to engage citizens.

Our study process is briefly outlined, by phase, in the following section. To this point in the study, more than 15,000 citizens have contributed, including 400 knowledge experts in scientific (natural and social sciences) and technical disciplines related to the management of used nuclear fuel.

2.2 / The Road Traveled – the NWMO's Process of Collaborative Development with Canadians

Phase 1 – Conversations About Expectations

We began the study by listening to Canadians about their expectations and objectives for the study. We asked Canadians to tell us:

- How should the study be conducted?
- What questions should be asked and answered in the study? and
- Which options should be investigated and included in the study?

As part of this 'listening and learning', we launched a number of initiatives, including a set of early conversations with Canadians, to begin to appreciate expectations both for the process to be used and the issues to be explored in the study. We also commissioned a series of expert papers and convened workshops to initiate some focused discussions on specific topics.

One of the major initiatives we launched in this phase was a Scenarios Exercise. Given the very long time-frames over which used nuclear fuel remains hazardous to people and the environment, decisions we make today will surely have repercussions for generations to come. Although we cannot know what future societies will look like, we can try to anticipate what they may look like by envisioning a broad range of possibilities. Envisioning possible futures that we might attempt to plan for in the decisions we make today was the objective of the Scenarios Exercise.

In partnership with Global Business Networks, we convened a Scenarios Team consisting of 26 individuals drawn from a range of interests and locations across Canada. Four workshops of several days each were held over the course of several months. At the end of the exercise, the group had described four detailed scenarios for the time-frame of 25 years from now, 12 much less detailed scenarios for the 175-year time-frame, 16 sets of conditions for the 500-year time-frame, and a number of simple "what-ifs" for the 10,000-year time-frame. A sub-set of these scenarios later came to form an important component of the assessment of approaches.

Table 2-1 Phase 1: What we did to identify expectations for the study

- We traveled across the country for face-to-face conversations with 250 individuals and groups involved in this issue including: people from communities that are currently storing used nuclear fuel; political representatives at all levels of government; Aboriginal leaders; nuclear power plant workers, youth, environmental organizations, industry experts, faith communities, government agencies and parliamentarians;

- We undertook public attitude research with a representative cross-section of Canadians, including: 14 focus groups (two in each of seven locations); and a nation-wide telephone survey involving 2,600 Canadians;

- We encouraged letters, submissions and comment from interested Canadians, through regular mail and through the NWMO's website (via formal submissions or deliberative surveys);

- We commissioned a series of papers designed to describe key concepts often used in the exploration of difficult public policy issues, to help guide and inform our examination and assessment of used fuel management approaches. These papers suggested important questions for the study to ask and answer. The concepts explored included: risk and uncertainty; security; the precautionary approach; adaptive management; and sustainable development;

- We convened a workshop involving a variety of traditional knowledge holders to explore the contributions of Aboriginal Traditional Knowledge to our study;

- We commissioned background papers from experts to describe the range of technical methods available, and the practicability and promise which each holds;

- We conducted a major scenarios exercise, which included a series of four workshops. A diverse group of individuals drawn from many interests was brought together with the task of identifying a range of plausible futures and conditions which might need to be faced in managing used nuclear fuel over the long term, and the questions those scenarios raise for the study;

- We convened a roundtable of experts in ethics, who would meet over the course of the study to help identify the ethical issues associated with the long-term management of used nuclear fuel and the conduct of the study;

- We convened a workshop with opinion leaders in communities that currently host interim storage facilities to explore ways to facilitate effective and responsive dialogue at the community level;

- We convened a workshop with senior practitioners in sustainable development to discuss what might be the key environmental questions that need to be addressed respecting the management of used nuclear fuel;

- We convened a workshop of 50 scientific and technical experts to discuss the key technical questions that need to be addressed respecting the management of used nuclear fuel, as well as the range of technical methods available, their promise and practicability;

- We began the process of creating agreements with national Aboriginal organizations, and some regional organizations to design and implement their own dialogue process as a means of providing input to the NWMO's study; and

- We conducted meetings with political representatives at all levels of government in Canada, and with international agencies involved in this issue.

Reports of these initiatives can be viewed at www.nwmo.ca/backgroundpapers and www.nwmo.ca/dialoguereports.

People needed good information as a foundation to become involved in the study. We commissioned a series of expert papers, which were peer-reviewed and then posted on our website. We asked more than 60 experts from a wide diversity of disciplines to help us understand the state of scientific and technical knowledge in both Canada and abroad on issues related to the study. These experts have also helped us to understand that although there is much that we know, there are still some areas of uncertainty.

This was the first step in creating an information foundation for the study. Over the course of the study, as information gaps were identified through public dialogue, additional expert papers were commissioned and workshops convened. Our information base expanded as Aboriginal Peoples began to contribute Aboriginal Traditional Knowledge to the study. Citizens from communities that currently store used nuclear fuel on an interim basis shared their experience 'living' with used nuclear fuel. The information foundation was also augmented by other citizens from the perspective of public values.

Table 2-2 Phase 1: What we did to create the information foundation for the study

More than 60 expert papers were commissioned on the following topics:

- Social and Ethical Dimensions. The papers were designed to suggest social and ethical dimensions of managing radioactive waste;

- Health and Safety. The papers were designed to provide information on the status of relevant research, radiological protection technologies, standards and procedures to reduce radiation and security risk associated with radioactive waste management;

- Science and Environment. The papers were designed to provide information on the status of relevant research on ecosystem processes and environmental management issues, including: research into our understanding of the biosphere, subsurface biosphere and geosphere; natural and anthropogenic analogues; chemical toxicity potential; and implications of climate change and of microbiological factors on the long-term management of used nuclear fuel;

- Economic Factors. The papers were designed to provide insight into the economic factors and financial requirements for the long-term management of used nuclear fuel, including: an examination of economic regions; status of financing systems for high-level radioactive waste management around the world; examination of economic considerations and analytical tools for the economic assessment of approaches;

- Technical Methods. The papers were designed to provide general technical 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. This includes: overview of reactor site storage, centralized storage, geological repository systems, other potential management options; the status and economic and radiological implications of nuclear fuel reprocessing, partitioning and transmutation for used nuclear fuel; transportation systems, storage disposal and transportation containers, transportation issues and considerations; exploration, from a geoscientific perspective, of the suitability of other geomedia, beyond that specified in the *Nuclear Fuel Waste Act*, for implementation of the deep geological repository concept; and potential design changes associated with implementation in other geomedia;

- Conceptual Engineering Designs and Cost Estimates for Alternative Management Approaches. The NWMO received and posted to the website a series of technical and engineering reports from the Joint Waste Owners: Ontario Power Generation, Hydro-Québec, NB Power Nuclear and Atomic

Energy of Canada Limited. The Joint Waste Owners commissioned engineering consulting firms to develop preliminary conceptual engineering designs for the three technical methods identified in the *Nuclear Fuel Waste Act*, and to develop associated transportation infrastructure and cost estimates for those designs. Upon receipt of this material, the NWMO commissioned a third-party review of this body of work, including examination of the key engineering design assumptions and cost estimation process; and

- Institutions and Governance. The papers were designed to outline the current legal, administrative and institutional requirements that may be applicable to the long-term management of used nuclear fuel in Canada, including legislation, regulations, guidelines, protocols, directives, policies and procedures of various jurisdictions. This includes: a compendium of current legislation, regulatory documents, treaties, guidelines, and plans; status of Canadian expertise and capabilities; review of Canadian Environmental Assessment Act Process, Canadian Nuclear Safety Commission licensing process, the Non-Proliferation Treaty; methodologies for assessing used nuclear fuel options; and education and training in nuclear waste management in Canada and abroad.

These background papers can be viewed at www.nwmo.ca/backgroundpapers.

Phase 2 – Exploring the Fundamental Issues

The second phase of the study was launched with the release of our first discussion document *Asking the Right Questions?* We reported back to Canadians what we had heard, and on this basis how we planned to proceed with the study. This discussion document identified:

- Our plan to break the study into 'bite-sized pieces', each of which would form the focus of a broad dialogue with Canadians and be the subject of a discussion document;
- A list of 10 questions which we heard that Canadians want asked and answered in the study, and which should set the agenda for the study; and
- The short list of technical methods that we heard hold the most promise, drawn from a list of 14 technical methods, which represents the range of choices considered internationally for the management of used nuclear fuel.

We launched a number of initiatives to engage citizens and specialized groups in discussion on four questions: Have we described the problem correctly? Have we identified appropriate ways to deal with the problem? Are we asking the right questions? Is our proposed decision-making process understandable and appropriate?

One of the most significant initiatives was a National Citizens Dialogue on Values. From the outset of the study, we identified the need for the study to be driven by the values of Canadians. To gain a more in-depth understanding of citizens' values, and to identify these values *explicitly*, we launched a collaborative research project with the Canadian Policy Research Networks.

A cross-section of citizens from coast to coast participated in the dialogue. In total, 462 Canadians gathered in 12 cities across Canada between January and March 2004, to talk with each other about the key characteristics they feel are important in a long-term management approach. This 'deliberative' dialogue identified one over-arching requirement and six 'fundamental values,' which later came to form foundation elements in the assessment framework.

A second major focus of activity in this phase of the study was the development of an Assessment Framework that reflected the values and concerns of Canadians. This framework was needed to help with the task of undertaking a rigorous comparative analysis of alternative management approaches. A multi-disciplinary Assessment Team assembled by the NWMO created the framework, based on the 10 questions outlined in our first discussion document. The team was asked to apply, in a preliminary manner, this framework to the short list of options specified in the *Nuclear Fuel Waste Act*.

The Assessment Team conducted its work over a six-month period, meeting as a group for a full week once each month. The framework developed by the Assessment Team, and the preliminary assessment which they performed, was a major input to our second discussion document.

Table 2-3 Phase 2: What we did to explore the fundamental issues

- The NWMO reported on what it had heard to date, how it incorporated what it had heard in its work going forward, and sought clarification and correction, with the release of its first discussion document, *Asking the Right Questions?* (www.nwmo.ca/askingtherightquestions);

- We convened workshops with citizen groups and organizations involved in this issue and individuals and organizations with an interest in public policy at both national and regional levels (National Stakeholder and Regional Dialogues and other individual and group meetings);

- We convened a workshop with young people involved in the nuclear industry (Roundtable Dialogue with Youth at the International Youth Nuclear Congress);

- We sought advice and guidance through dialogues designed and implemented by Aboriginal Peoples. (www.nwmo.ca/aboriginaldialogues);

- We commissioned public attitude research with a representative cross-section of Canadians, including: 10 focus groups (two in each of five locations) and a nationwide telephone survey involving 2,600 Canadians;

- We received letters, submissions and comments from interested Canadians through regular mail and through the NWMO's website (via formal submissions or deliberative surveys).

- We held an in-depth exploration of values through a National Citizens' Dialogue with citizens, to identify and explore the values which we share as Canadians, and which should drive decision-making on this issue;

- We held ongoing meetings with political representatives at all levels of government in Canada, and with international agencies involved in this issue; and

- We created a multi-disciplinary group to develop an assessment framework based on the direction that had emerged from dialogue with Canadians, and to apply this framework in a preliminary way to the management approaches under study. (www.nwmo.ca/assessmentteamreport)

Reports of these initiatives, unless otherwise indicated, can be viewed at www.nwmo.ca/dialoguereports.

Phase 3 – Evaluating Management Approaches

The third phase of the study was launched with the release of our second discussion document *Understanding the Choices*. Through this document, we reported to Canadians what we had heard in the previous phase, and how we planned to proceed with the assessment of approaches. This discussion document:

- Reported on further learning about the values and priorities of Canadians concerning the long-term management of used nuclear fuel, and insights from dialogues convened around the first discussion document;
- Provided more complete descriptions of the approaches that had become the focus of the study; and
- Outlined a proposed framework to be used for the assessment of management approaches, composed of citizen values, ethical principles and specific objectives. This framework was designed to build on the 10 questions that had been identified through conversations with Canadians and largely confirmed through subsequent dialogue.

With the release of this document, we asked Canadians if the proposed assessment framework was sufficiently comprehensive and balanced. That is, does the framework reflect the values and objectives of Canadians? We also asked interested Canadians to help apply the framework to the approaches and identify the relative strengths and weaknesses of each of the approaches. In dialogue leading up to the second discussion document, we had begun to hear that the way in which any management approach is implemented is very important, perhaps as important as the approach itself. For this reason, we also posed the following question to Canadians, are there specific elements that you feel must be built into an implementation plan?

To continue the dialogue, we collaborated with the independent consulting firm DPRA Canada, to organize a series of 120 public information and discussion sessions in locations across Canada. These sessions were advertised broadly to invite all interested Canadians to meet with us, learn about the study, and contribute to the assessment of the approaches.

We also reconvened some of the individuals and groups who had met to discuss our first discussion document. These National and Regional Stakeholder Dialogue workshops convened by the independent consulting firm Hardy, Stevenson and Associates Ltd., brought together individuals from specialized organizations and groups, such as environmental groups, learned societies, the nuclear industry, faith groups and others involved in this issue.

Finally, we furthered the exploration of the strengths and limitations of the approaches under study by commissioning a group of experts to take the framework outlined in the second discussion document, and modified through dialogue, and conduct a rigorous assessment of the management approaches under study. We commissioned this additional and complementary assessment work, conducted by independent consultants well known in this area (Golder Associates Ltd., Gartner Lee Ltd.), to extend the assessment to include consideration of illustrative economic regions in which each of the approaches might be sited and more formal quantification of risk.

This phase of work concludes with this document, the Draft Study Report, in which we outline our thinking concerning the recommendation we plan to make to the federal government.

Table 2-4 Phase 3: What we did to further the assessment of management approaches

- The NWMO reported on what it had heard to date, how it had incorporated what it had heard in its work going forward, and sought clarification and correction, with the release of its second discussion document, *Understanding the Choices*. (www.nwmo.ca/understandingthechoices);
- We convened a series of 120 public information and discussion sessions across Canada, which invited interested Canadians to meet to discuss the second discussion document;
- We received advice from Aboriginal Peoples through dialogues they designed and implemented;
- We commissioned three e-dialogues on the difficult topic of risk and uncertainty as it applies to the long-term management of used nuclear fuel. These involved two learned panels, and a series of e-roundtables among graduate students and other young people;
- We commissioned public attitude research with a sampling of Canadians, including 10 focus groups (two in each of five locations), as well as deliberative surveys on our website;
- We convened a workshop which brought together a variety of individuals with knowledge in natural science, social science and Traditional Aboriginal Knowledge, to discuss how the nature of the hazard inherent in used nuclear fuel might best be characterized;
- We received letters, submissions and comment from interested Canadians through regular mail and through the NWMO's website (via formal submissions or deliberative surveys);
- We convened a series of workshops with citizen groups and organizations involved in this issue (National Stakeholder and Regional Dialogues);
- We convened a series of meetings and workshops with individuals in communities that currently host nuclear waste facilities;
- We convened a roundtable with key public policy analysts and opinion leaders;
- We held ongoing meetings with political representatives at all levels of government in Canada, and with international agencies involved in this issue;
- We commissioned a team of experts to take the Assessment Framework developed by the Assessment Team, based on direction which had emerged from public dialogue, and conduct a rigorous and integrated assessment of the management approaches under study with respect to economic regions. (www.nwmo.ca/assessments);
- We commissioned experts to supplement the analysis with additional work to examine the management approaches from the perspective of risk. (www.nwmo.ca/assessments); and
- The NWMO outlined its thinking on the recommendation it plans to make to government, its thoughts on how this recommendation is responsive to the advice and guidance of Canadians, and seeks comment before formulating its final recommendation with the release of this document, the *Draft Study Report - Choosing a Way Forward*. (www.nwmo.ca/draftstudyreport)

Reports of these initiatives, unless otherwise indicated, can be viewed at www.nwmo.ca/dialoguereports.

Phase 4: Finalizing the Study Report

With the release of this Draft Study Report, the fourth and final phase of our study begins.

In this phase, we have planned a number of initiatives to continue the dialogue with interested Canadians on our planned recommendation. We have committed to listening and learning from Canadians, even in this final phase, before finalizing our recommendation to Government.

As outlined in the *Nuclear Fuel Waste Act*, we will deliver our recommendation on a preferred management approach on or before November 15, 2005.

Table 2.5 Phase 4: What we plan to do to finalize the study

We will fine-tune our recommendation in response to comments made by Canadians on the Draft Study Report;

- We will conduct public attitude research with a representative cross-section of Canadians;
- We will encourage letters, submissions and comments from interested Canadians through our website (via formal submissions or deliberative surveys);
- We will reconvene those interested Canadians who have contributed to our study in workshop sessions in at least four provinces – New Brunswick, Québec, Ontario and Saskatchewan – to examine and comment on the Draft Study Report;
- We will receive advice and guidance from Aboriginal Peoples at the national and local levels, as their dialogue process continues;
- We will conduct meetings with political representatives at all levels of government, and with international agencies involved in this issue; and
- We will then deliver our recommendation to Government on a preferred approach for the long-term management of used nuclear fuel.

CHAPTER 3 / WHAT PEOPLE TOLD US

During these more than two years of dialogue with Aboriginal Peoples, the public and knowledge experts, we have received very specific direction on both the way in which we should assess the management approach options, and the advantages and limitations of each as judged by interested Canadians. After reviewing each of the three options which form the focus of the study, many suggested to us that an additional option should be considered, an option that would attempt to combine the approaches to capitalize on the advantages of each. Finally, we heard that the way in which a management approach is implemented is as important to its acceptability as the technology used. We have received very specific direction on the requirements of an appropriate implementation plan.

The summary that follows in this chapter describes the highlights from this dialogue. In Part Three of this report, we discuss how we have incorporated what people told us in our assessment of the management approaches, and in the design of an additional management approach for consideration.

3.1 / What is Important in a Management Approach?

We asked citizens to help us understand the values and objectives which any used nuclear fuel management approach for Canada should address. The following is a summary of what people told us. It is compiled from the consultants' reports of findings from dialogue activities, and submissions to our website.

Basic Points of Debate

Over the course of our dialogue with Canadians much common ground has emerged. This common ground reflects a set of values and objectives that we as citizens appear to share and which can form a basis on which to move forward on this issue. We also heard people actively debate some questions which, for them, are fundamental to the choice of a management approach for used nuclear fuel. Around these questions, the common ground is less apparent.

We report below on some fundamental questions on which we heard the views of Canadians diverge. For the most part, these questions are beyond the mandate of our study. However, the divergence of view on these questions infuses many of the comments we heard about the management approaches. The differences in perspective on these questions are important influencing factors, which the study must recognize, although it cannot directly address.

Some have suggested that this divergence is a result of the imperfect distribution of knowledge among those who have engaged in the study. If all had the same level of knowledge and understanding, the argument goes, the diversity of opinion would be much reduced. They suggest that public education and communication will bring us together.

Others have suggested the source of divergence is more fundamental, and reflects real and substantial differences in perspective. Our efforts to both create a balanced portrayal of information and to broadly communicate this information to the interested public, leads us to believe that the divergence in perspective on these issues is substantial and warrants further exploration in a separate public policy forum.

Should the nuclear generation of electricity be continued?

From the inception of our study, a number of people told us that the assessment of management approaches needs to be undertaken in the context of a broader public policy debate about energy. Nuclear energy as a way of generating power, some argue, needs to be fully assessed in comparison with other ways of generating power. Others go further in arguing that discussions about the long-term management of nuclear fuel waste cannot be reasonably separated from discussion about the rest of the nuclear fuel cycle, including the mining of uranium ore.

Many of those who advocate for such a broad framing of the issue suspect that nuclear energy generation would be abandoned if the costs and benefits of the full life cycle were examined. For these people, until such an assessment is made, concern about the appropriateness of nuclear energy will continue to be a stumbling block to the discussion of waste management approaches.

Not all Canadians we spoke with shared this view. Many took an opposite view, and suggested that an assessment of energy generating methods would show nuclear energy to be a responsible choice, a form of energy that improves the quality of life of people around the world today and will continue to do so in the future. These Canadians did not see the nuclear energy question as an issue that must be addressed before waste management approaches are considered.

Finally, some suggested that since waste exists, it must be dealt with, irrespective of the future of nuclear power in Canada. For these people, the question of whether nuclear generation should continue is irrelevant to our study.

Do we have sufficient knowledge to proceed with decision-making?

All those with whom we have spoken agree that Canada, as well as other countries, have assembled a large body of knowledge to help inform decision-making on the long-term management of used nuclear fuel. This is particularly the case when we compare the body of knowledge on this issue with the amount of knowledge that supports many other kinds of social decisions that we make with relative ease. We have a large group of scientific and technical experts in Canada, many of whom are internationally renowned, to help us make wise decisions on this issue. Our knowledge on this issue is substantial. On this we have heard broad agreement.

Where we have heard active debate is on the question of whether this large body of knowledge is *sufficient* to proceed with decision-making now, particularly whether it is sufficient to make a decision on an 'ultimate solution' which will have implications for many generations to come. It is the time dimension of this issue, the fact that the used nuclear fuel must be effectively contained and isolated from people and the environment for a very long period of time, which gives rise to an important question. Given the long period of the hazard, and the fact that we have much knowledge although some uncertainties remain, what does a cautious approach dictate? And, what does responsible action require?

As we continue our efforts to understand and inform Canadians about the foundation of information available for decision-making, it is important to note that those who are most closely involved in the design of the management options and who have been at the forefront of scientific and technical exploration and testing, are confident in both the safety of the various technical methods for managing the fuel and our capacity to proceed with whichever Canadians may judge to be appropriate.

For which vision of the future should we be planning?

It is apparent that some have a more optimistic perspective on what the future holds than do others. This is evident in how Canadians have viewed the appropriateness of each of the approaches. If you feel that social structures may collapse in the future, you are more likely to consider a management approach that does not rely on social institutions to contain and isolate the material than on approaches that require institutional oversight. Similarly, if you believe that science will discover new and better management approaches in the future, then you are less likely to want to seal used nuclear fuel away and make it inaccessible. It is apparent from our conversations with Canadians that there is no one single view of the future that we all share, and feel should be the focus of planning.

The Common Ground: An Assessment Framework

With the release of our second discussion document, we largely heard that we had identified the range of values and objectives that should be considered in assessing options and identifying a preferred approach.

In general, dialogue participants from across the country expressed comfort with the breadth and depth of the values, ethical principles and objectives which make up the Assessment Framework which should drive the assessment of the options. Participants found that the framework is balanced, and did a good job of reflecting what Canadians view as the important considerations for selecting a long-term approach for the management of used fuel.

Many participants told us they were pleased to see that the societal values and ethical considerations were being applied alongside the more conventional technical and financial considerations. For many this was viewed as a positive step forward, and begins to address one of the key findings of the Seaborn Panel's report that the long-term management solution must not only be technically feasible but also socially acceptable. There also appeared to be widespread recognition among participants that finding a long-term solution for the management of used fuel is both controversial and difficult. As a public policy issue this is a complex and multi-dimensional challenge and the development of an Assessment Framework that incorporates all considerations will provide a foundation for a more complete and more objective assessment of options. Several participants noted that the inclusion of societal values and ethical considerations was a significant improvement over other past efforts to manage used nuclear fuel.

While there is much common ground on what is important for a management approach in terms of values, ethical principles and objectives, it is apparent from our dialogues with Canadians that we don't all agree what fulfillment of that value, principle or objective would look like. This forms part of the social dilemma to be addressed in the selection of a management approach, and is outlined in more detail in the commentary that follows. This commentary is designed to briefly highlight what participants in dialogues said about each of the elements of the framework.

Citizen values which should inform the selection of a preferred approach

Safety from harm

An overarching requirement. First and foremost, human health and the environment must be as safe as possible from harm, now and for the future.

Safety from harm was identified by participants as being the most important value. Regardless of which management approach is selected, people told us that the approach must, to the greatest extent possible, ensure that no harm is done. People had various definitions for safety, but most expressed very clearly and strongly that safety must be assured for all people (public and workers), and for our environment. They said safety must be assured for both today and the future.

As will become evident in the discussion of the perceived advantages and limitations of the management approaches, there were different interpretations of how to best achieve safety. Some participants felt that the used fuel should remain at the reactor sites, where it is above ground and easily accessible. In this way, society would be constantly reminded of the used fuel, and monitoring and safeguards would be easily maintained, thus ensuring a high level of safety to people and the environment. At the other end of the spectrum, others felt that because of uncertainty regarding the stability of future society and the potential lack of commitment of future societies to properly manage the used fuel, the best way to ensure safety would be to dispose of the used fuel below ground and to seal it for all time.

Responsibility

We need to live up to our responsibilities to ourselves and to future generations, and deal with the problems we create.

People told us that responsibility was an important value to guide the selection of a management approach. There appeared to be a consensus that we have an obligation to take action now to properly care for and manage the used fuel. However, there was no agreement as to what type of action Canada needs to take.

For many, taking responsibility means ensuring that we fully understand the nature of the waste management challenge, assess a full range of options, ensure that the necessary studies, procedures and protocols are in place, confirm that the current storage of wastes is safe and reliable, and ensure that the funds are in place to accommodate any future action for the long-term management of the used fuel. This does not include taking responsibility for a final decision now, but suggests leaving it to future generations to determine. For these people, our responsibility is to ensure that the conditions are in place to accommodate any future decision without placing future generations at risk from a safety or a financial perspective.

Others felt very strongly that it is our generation's responsibility to make a final decision that will ensure the long-term management of used fuel. We have the knowledge and capacity now to take this action, and we should use it. This includes selecting a management approach that completely addresses the final management of used fuel, and doing this within a relatively short period of time. From this perspective, our responsibility is to ensure that we resolve this matter and not leave this as a burden for future generations.

Adaptability

We need to build in capacity to respond to new knowledge.

People told us that adaptability is very important. One of the significant themes that emerged is that people generally are optimistic that society will continue to learn and discover new ways to do things. Of particular importance is that the selected management approach anticipates and is able to accommodate the potential for new information and technological advancement. No management approach should preclude consideration of new information, and any strategy must allow for a change in approach if any new information means that the used fuel can be better managed.

Some participants suggested that technological advancement might mean that the used fuel can efficiently and effectively be re-used as a future energy source. In anticipation of this, the selected management approach must allow for the used fuel to be accessible and retrievable. Thus, we should not make a decision today that would preclude the possibility of applying new knowledge for managing this material. Several suggested that part of our responsibility was to investigate and research emerging technologies and to assess their potential for the future management of used fuel.

Stewardship

We have a duty to use all resources with care and to conserve, leaving a sound legacy for future generations.

Participants talked to us about the need to use our resources wisely to ensure that they will be available for possible future use. Some suggested that stewardship means that Canadians have a responsibility to manage used nuclear fuel found in other countries that has been produced by Canadian nuclear technology. A minority went as far as to suggest that full stewardship would imply that Canada should provide support and assistance to less fortunate countries for the proper management of their used fuel. Others, including the majority of participants in Aboriginal Dialogues, argued strongly that our responsibility extends only to the used nuclear fuel that we have created and used in Canada.

Accountability and Transparency

Governments are ultimately accountable for the public good concerning safety and security, but must involve citizens, experts and stakeholders in any decision-making. Honour and respect must be shown for all.

Participants consistently commented on the importance of being able to have confidence that those entrusted with the responsibility of protecting the public interest are doing a good job. Decisions must be made in the long-term public interest, and not for political expedience or short-term profit. These decisions must involve the public. To be accountable, any individual or organization must be seen to be focused on the public interest and open to scrutiny.

Consistently throughout the dialogue, concern has been expressed by some participants about the track record of the nuclear industry and government in terms of accountability and transparency. Many examples have been brought forward of incidents in which the industry and/or government have acted in what is perceived to be a self-interested and secretive manner. For these participants, this is a key area in which trust must be built before proceeding with any approach for the long term management of used nuclear fuel. The fact the Board of Directors of the NWMO is composed only of waste producers causes some to question the extent to which such an organization can be fully accountable to the public interest.

Knowledge

We need to continue to invest in informing citizens, and in increasing knowledge, to support decision-making now and in the future.

Participants suggested that knowledge is also of great importance. In order for Canada to make a wise decision on the future management of used fuel, Canadians need to be aware and informed. Some participants identified the need to build awareness and public understanding of the challenges associated with used nuclear fuel management. Others commented that with the many demands that face most Canadians, it would likely be very difficult if not impossible to raise awareness of and knowledge about this issue.

Overall, participants suggested that complete, objective and balanced information and research must be provided. The potential for new knowledge and learning, including from Aboriginal Traditional Knowledge, needs to be recognized and accommodated in our recommendation to government.

Inclusion

The best decisions reflect broad engagement and many perspectives; we all have a role to play.

Participants identified the active involvement by all interested parties in the development and selection of a management approach as a fundamental requirement. Many felt that the selection of a management approach for used fuel should not be made in isolation by experts and politicians. The development of the approach must allow for all Canadians to provide views and opinions.

Ethical principles which should inform the selection of a preferred approach

Respect for Life

in all its forms, including minimization of harm to human beings and other sentient creatures; Respect for People and Cultures.

Participants in the dialogues were largely unanimous in identifying Respect for Life as the most significant ethical principle to guide decision-making. Many equated this principle with the Safety From Harm value. Both suggest that whatever action is taken to manage the used fuel, it must respect all forms of life.

From the perspective of many participants, demonstrating Respect for People and Cultures is intimately related to demonstrating a respect for life more generally.

Respect for Future Generations

of human beings, other species, and the biosphere as a whole.

No ethical principle generated more discussion among participants than that of Respect for Future Generations. Many suggested that we should not prejudge the needs and capabilities of the future. Rather than acting in a paternalistic way, we should leave the choice of what to do with the used fuel for them to determine. There was a strong sense among some of the participants that the used fuel may represent a potential resource for future generations, and the decisions and actions taken by this generation should not foreclose future opportunities. In this context, our generation would show respect for the future by ensuring that the used fuel is properly cared for but made available to the future for possible use.

Others, although fewer, argued that the principle clearly meant that this generation must take all the necessary action to not leave to future generations a burden or a problem that we created. In particular, because of uncertainty about the stability of future societies and uncertainty regarding their technological and financial capabilities, we need to make a final decision to ensure that the used fuel created by this generation is fully and properly managed.

Justice

across groups, regions and generations; fairness – to everyone affected and particularly to minorities and marginalized groups.

Most participants linked the principles of justice and fairness together. Some suggested that fairness and justice are difficult to define in the context of this issue, and is subject to multiple interpretations. How is fairness to be determined? Who determines it? What is geographic fairness? Is it possible to be fair (equally fair) to everyone who may be affected by the decision? And, how do we make sure that those who are most vulnerable, that is minorities and marginalized groups, are not unfairly burdened by any decision made? In this context some participants suggested that regardless of the selected management approach there would be some who will benefit and some who will bear the costs.

Some participants suggested that, when all the values, principles and objectives are taken into consideration, some difficult trade-offs will have to be made. When making these trade-offs, many expect that fairness cannot be assured. In particular, they suggested that in order to ensure safety from harm, fairness might need to be compromised.

Sensitivity

to the differences in values and interpretation that different individuals and groups bring to the dialogue.

Many participants commented on the importance of a wide cross-section of Canadians being engaged in decision-making on this issue, and the importance of understanding and considering the views, opinions and concerns that all people have regarding the future management of Canada's used fuel.

Objectives which should inform the selection of a preferred approach

Public Health and Safety

To ensure public health and safety.

Public health and safety was uniformly considered the most important of the objectives, and has been the focus of discussions throughout the study. For many participants, this is the key issue to be addressed and other values and objectives are only important to the extent that they contribute to ensuring the health and safety of individuals and the population. Some participants told us that public health and safety necessarily encompasses 'worker health and safety' and 'community well-being.' Others told us that 'security' and 'environmental integrity' were also an integral part of a broader notion of safety, a notion focused on keeping the used fuel contained, and ensuring people are not harmed. Participants in focus groups in particular identified this as the only "must have" element of a management approach.

Fairness

To ensure fairness (in substance and process) in the distribution of costs, benefits, risks and responsibilities, within this generation and across generations.

Consistent with discussion of the ethical principle of the same name, Fairness was viewed as an important objective against which any management approach should be measured. It was the subject of much discussion and difference of view, about how fairness should be judged.

Worker Health and Safety

To ensure worker health and safety.

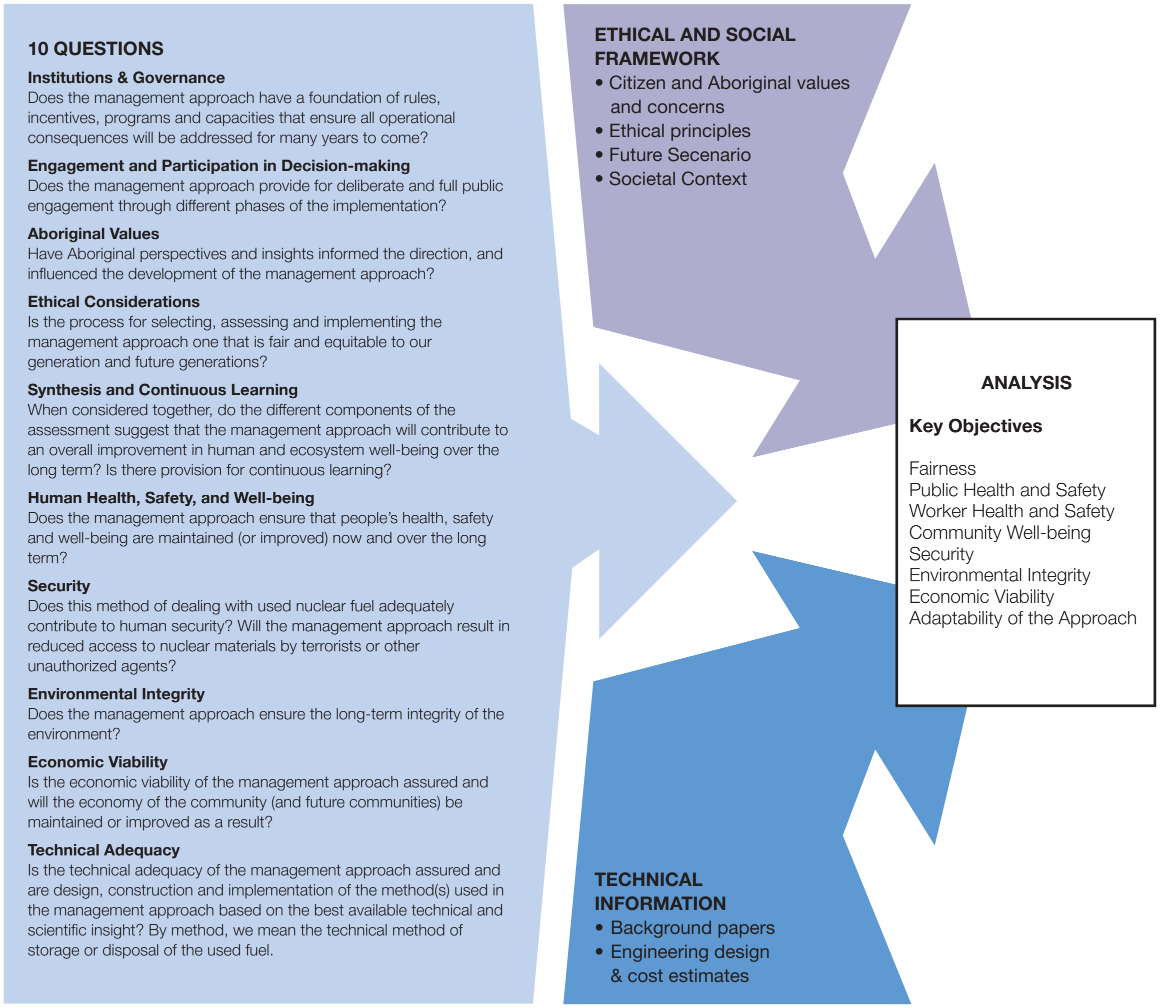
Many dialogue participants commented on the importance of Worker Health and Safety, and the need to consider separately the health and safety of the public and the health and safety of workers. Generally, participants felt it is appropriate that the standard of judgment for these two be different since workers willingly and appropriately take on greater risk as a result of their occupation.

Community Well-Being

To ensure community well-being.

Many participants struggled with the question of what constitutes a "community." Participants suggested that it should not be defined as just the community that might host a management facility, but should include any community of interest or group of individuals that might be affected either directly or indirectly by the management approach. This would include communities along potential transportation routes, the current reactor site communities, and any community, organization or group (i.e., an environmental group) that may be affected from an ecological, economic and social perspective. Participants in the Aboriginal Dialogues expressed particularly strong concern about the need to define "community" broadly. There was also much discussion, without resolution, concerning how we might balance the needs and demands of different "communities" when these demands inevitably conflict.

Figure 2-3 **Inputs for the Assessment**



Security

To ensure security of facilities, materials and infrastructure.

Participants felt that security was an important objective. Many saw security as what is required to respond to the citizen value of Safety from Harm and also to the ethical principle of Respect For Life. As such, it is an important companion to safety.

Participants offered a range of opinions as to how security is best assured in discussion of the different management approaches.

Environmental Integrity

To ensure environmental integrity.

In talking to us about the objective of Environmental Integrity, many people told us they consider this a necessary component of ensuring public health and safety. For many, it is not conceivable that we would be able to achieve Public Health and Safety without Environmental Integrity.

Economic Viability

To design and implement a management approach that ensures economic viability of the waste management system while simultaneously contributing positively to the local economy.

Participants commented on the importance of ensuring that adequate funding be in place to implement the approach, regardless of the management approach selected. Many commented, however, that management costs should not drive the selection of an approach at the expense of the other objectives, particularly public health and safety and community well-being.

Adaptability

To ensure a capacity to adapt to changing knowledge and conditions over time.

As discussed in the context of the citizen value of Adaptability, there was much discussion of the need to treat adaptability as an objective for any management approach. It is viewed as being a fundamental requirement. Some participants expressed optimism that as a society we will continue to learn and develop new technology. As a result, the future may well hold the key to a better solution over the long term for the management of the used fuel. The approach that is selected must recognize and accommodate the potential for new knowledge to influence the final solution.

Some participants commented that adaptability is important in that it allows for contingencies within a management approach that can both anticipate and address changing conditions the significance of which are unknown to us today. The potential for climate change and future societal breakdown were often cited as two examples of changing conditions that need to be considered in the assessment of management approaches.

3.2 / Special Insights from the Aboriginal Dialogues

Aboriginal Peoples are an important community of interest for this study, as reflected in specific direction to the NWMO through the *Nuclear Fuel Waste Act* (*NFWA*) to seek the comment of Aboriginal Peoples. In the past Aboriginal leaders have specifically requested an opportunity to study the question of management of nuclear waste. They have advised us to think of the impact of our actions seven generations hence, and to incorporate traditional ecological knowledge.

The goal of our Aboriginal Dialogues is to build the needed foundation for a long-term, positive relationship between the NWMO and the Aboriginal Peoples of Canada. We have initiated agreements to support national, regional and local organizations in designing and implementing their own dialogue process as a means of providing input to our study. As a result of this support, some 80 meetings, workshops, community retreats, presentations and discussions have been held, involving more than 2,000 people. Many others were involved through informal discussions. Specific detail is provided in Appendix 5.

Over the course of these meetings, some individuals and groups have suggested that the pace of our study does not leave sufficient time to allow participants to digest the complexity of the issue. Some have also voiced concern that we have not adequately drawn on, and provided information about, previous involvement by First Nations with the uranium and nuclear industry.

The observations that are summarized in this section are drawn from the reports that Aboriginal groups have filed with us, and they are available for viewing in their entirety on the NWMO website. (www.nwmo.ca/aboriginaldialogues)

Many of the observations and insights offered during the various elements of the Aboriginal Dialogues are consistent with those gathered during our broader public dialogue. In particular:

- The highest priority concern expressed is for safety and security for people and the environment;

- Many Aboriginal participants spoke in favour of reducing the use of energy in general and nuclear energy in particular. They argued that the waste management issue cannot be fully resolved without a discussion of energy policy and the long-term role of nuclear energy. Further, they suggested there is a need to address the full cycle of nuclear materials from mining through long-term management of waste, including low and intermediate level radioactive wastes;

- Waste importation is not acceptable to most Aboriginal Peoples and there is concern that this is not explicitly rejected in the *Nuclear Fuel Waste Act*. Some concern was expressed that the North American Free Trade Agreement might force Canada to import nuclear waste from the United States, and this could be extended to bring in waste from other countries;

- There is a belief that more research is needed on such topics as the nature and extent of associated risks, methods for eliminating the hazardous nature of nuclear fuel waste, development of alternative energy sources and storage containers. As well, there are calls for conducting research and monitoring of international research efforts into advanced technologies for the reprocessing, partitioning and transmutation of wastes as well as Traditional Knowledge and its application.

In addition to such observations held in common with the general public, a number of contributions were offered that reflect a special perspective that derives from the particular history, experience, and concerns of Canada's Aboriginal community.

The Issue of "Consultation"

This is a complex legal issue concerning how Aboriginal Peoples see "consultation" under the Canadian Constitution. The Assembly of First Nations, Congress of Aboriginal Peoples, Ontario Aboriginal Métis Association, the East Coast First People's Alliance, the Western Indian Treaty Alliance, and the Atlantic Policy Conference of First Nation Chiefs all argue that our Aboriginal Dialogues do not consist of "consultation" as required by their interpretation of the law.

Fairness in the Distribution of Costs, Benefits, and Risks

The Aboriginal community is concerned that the costs, benefits and risks related to this issue be fairly distributed. Many suggested that urban dwellers will argue that a more northern and rural location, where most Aboriginal communities are found, would be a preferable site for waste management facilities because it would be considered "remote" from concentrations of population and therefore safer. However, in their view this kind of attitude unfairly characterizes the north as "empty" of people when in fact it is the home of Aboriginal Peoples and other northerners.

Many Aboriginal Peoples feel that few if any benefits realized by nuclear energy have accrued to them. In fact, some feel they have been negatively impacted by components of the nuclear fuel cycle, such as uranium mining. For them, the idea that traditional Aboriginal territory would be targeted for hosting a waste management facility is both unfair and unacceptable.

However, others see the potential for gain from a waste management facility in terms of long-term economic and social stability and have expressed an interest in perhaps further exploring the idea. But, they need to be assured the safety and security for people and the environment can be maintained, for that is a non-negotiable requirement.

In addition to the above perspectives, concern was expressed that financial leverage may be used to persuade an economically depressed Aboriginal community to accept the used nuclear fuel. This would be unfair and inappropriate.

Trust

Some expressed a deep suspicion towards government, the nuclear industry, the power utilities, the Nuclear Waste Management Organization, and this Dialogue. Many Aboriginal people commented on their experiences with various industries and government, saying they had lost trust in these institutions, and in some cases even feared harm would come to their communities and traditional territory from a nuclear waste management system.

However, others have expressed a willingness to leave the past behind and begin to work towards building a relationship of respect while contributing to finding the needed strategy for managing used nuclear fuel over the long term.

Recognition of Aboriginal Rights, Treaties and Land Claims

Many participants in the Aboriginal Dialogues expressed concern that the *NFWA* does not mention, and that we have not made explicit, reference to respecting Aboriginal rights, treaties and land claims. For these individuals, a first step in establishing the needed trust would be a formal commitment on the part of the NWMO to respect Aboriginal rights, treaties and land claims.

Traditional Wisdom and Knowledge

In September 2003, we convened a workshop to examine how Traditional Wisdom and Knowledge could be brought to bear on our task. In subsequent phases of the Aboriginal Dialogues, the results of the workshop were extended as participants added insight.

From these activities, it appears to us that Traditional Wisdom and Knowledge includes both an understanding of nature and of human relationships. It sees humans as part of the environment and spirituality a component of all relationships. It honours the wisdom of elders, whether they be from Aboriginal or non-Aboriginal communities. It looks to collective benefits for both the short and long term, and uses the concept of planning ahead for seven generations.

Participants in our Traditional Knowledge Workshop identified five values or principles associated with Traditional Management Practice:

Honour the wisdom that can be garnered from speaking to the elders in both the Aboriginal and non-Aboriginal community.

Respect the opinions and suggestions of all who take the time to provide insight into the process.

Conservation, particularly as it applies to consumption of electricity.

Transparency, particularly when NWMO (the producer of the problem) has to suggest the solution.

Accountability so those responsible (whether for the concept or delivery) are held to high account by the public for actions, given the nature of the problem.

This means that any NWMO process would involve letting the elders and wisest speak first, praying for assistance to make good decisions, constantly growing and changing with new insights, involving the whole community, and considering all matters over a period of seven generations. It would recognize that people are part of and guardians of the land, understand and apply the consequences of breaking traditional law, and ensure strong accountability is integrated into the management strategy. This would involve consideration of the biophysical, economic, social, cultural and spiritual aspects of the environment while maintaining an emphasis on interrelationships.

Traditional Knowledge provides rules for protecting while using the land; clarifying and enhancing relationships amongst users; assisting in the development of technologies to meet the subsistence, health, trade and ritual needs of local people; and helping to create a world view that incorporates and makes sense of all of the above in the context of a long-term, holistic perspective in decision-making.

The Centre for Indigenous Environmental Resources in Winnipeg identifies four aspects of Traditional Wisdom and Knowledge:

- Process related insight. This is about who talks, when to talk, how to talk, and the appropriate protocols for relationship building and decision-making;
- Special knowledge related to the land. This is site specific, and can be held by not only indigenous people but also by anyone who has long lived on the land;
- Values. These reflect the special importance of the environment, recognition that humans are part of that environment and a commitment to a holistic perspective that sees the encompassing system as much as the component parts; and
- Spirituality. This serves as a weave across everything, but there is no single expression.

Thinking about the application of Traditional Knowledge and Wisdom is helpful for clarifying how we can work with Aboriginal People in the years ahead.

The Issue of Responsibility

The Aboriginal community is split on the issue of responsibility. On the one hand, some point out that Aboriginal People were not asked to participate in the decision of whether or not to proceed with the generation of used nuclear fuel, and thus the responsibility for addressing the used fuel issue is not theirs.

However, others speak of the responsibility of Aboriginal Peoples and all Canadians to manage these wastes. They signal a desire to play a part in designing the management strategy. Even though nuclear fuel waste was not created by Aboriginal Peoples, they see the need for action now to address the issue.

Ongoing Engagement

Despite some concerns about the current process and its legal implications, there is a consistent call for an ongoing effective engagement program to help design and implement the way forward. Some call for creating an independent oversight capacity for Aboriginal Peoples covering any plan that is put into effect. All emphasize the need for information that is culturally and linguistically appropriate to ensure effective engagement.

Many strongly emphasized the need to engage directly with communities that might be affected by any management strategy.

Many say that there is a need to involve young people since they will be the ones addressing this matter in the future. There is a call for “building bridges for young people to develop their views, to carry traditional ways in new and different ways.”

A majority of the participating Aboriginal groups, either formally or informally, express concerns that representation of Aboriginal People within our teams and as staff people is inadequate. They would like to see this addressed by the NWMO as we proceed to implementation. We note that many of the Aboriginal processes and dialogues are currently underway, and have yet to reach a stage where they can provide specific commentary on the management approaches described in this report.

In our work with Aboriginal Peoples the NWMO explicitly sought to break away from earlier and past approaches to consultation, and deliberately invested in new and innovative approaches – encouraging engagement and dialogue. We have sought, and continue to seek to establish the foundation of a relationship that can be based on trust and mutual respect.

3.3 / The Advantages and Limitations of the Options

We asked Canadians to help us understand the advantages and limitations of the three management approaches under study, as they saw them. The following is a summary of what people told us about the strengths and limitations of each of the management approaches. This summary is compiled from the consultant reports of findings from dialogue activities concerning our second discussion document, and submissions to our website.

Option 1: Deep Geological Disposal in the Canadian Shield

The management approach is:

- Long-term management of used nuclear fuel through containment and isolation in a deep geologic repository in the granitic rock of the Canadian Shield;
- Used nuclear fuel is transported from the nuclear reactor sites to a central location for long-term management;
- The deep geologic repository is based on the concept described by Atomic Energy of Canada Limited in the Environmental Impact Statement on the Concept for Disposal of Canada’s Nuclear Fuel Waste, and modified to take into account the views of the environmental assessment panel as reported in February 1998;
- Following an interim period of monitoring, the repository is closed, without the intent to retrieve the used fuel.

Strengths of the Approach

Several advantages were suggested concerning this management approach including: the opportunity to isolate the used fuel from people and the environment in a permanent or definitive way, and the opportunity to remove the burden of management from future generations.

Many participants identified the potential of this management approach to provide high levels of safety to both people and the environment. Those that held this view indicated that the placement of the used fuel bundles at depths of 500 to 1,000 metres, in a highly stable and consistent geologic setting, has the potential to provide the greatest certainty that the used fuel will not cause harm over the long term. Except for the possible future development of cost-effective and proven technologies that would completely neutralize the used fuel, this management approach was suggested by many to be the best opportunity to isolate or remove the used fuel from human beings and the environment.

Many participants felt that through proper siting, site-specific studies, and appropriate engineering and construction, the used fuel could be placed and left for the long term without contaminating ground or surface water. Through the multiple barriers and passive containment associated with this approach many felt this method would be safer than the storage options. Additionally, the fact that the used fuel would be sealed underground is seen to greatly minimize the potential for access by terrorists who wish to either sabotage the repository or use the used fuel for an undesirable purpose. Some also suggested the robustness of this approach against accidental human intrusion as an additional advantage.

For some participants, an advantage of this approach is that it allows for a permanent solution now as opposed to storage approaches which "defer a final solution to the future." Developing the repository, whether it is used immediately or at some time in the future, would be a proactive and responsible action taken by this generation to resolve the issue surrounding the management of the used fuel. In other words, some considered this approach fairer to future generations than the other two approaches. Some suggested the approach could be modified to allow for retrievability and additional monitoring. This, in order to allow future generations the option to retrieve the fuel for another purpose or to permanently seal the repository at an appropriate time.

Some participants suggested the deep geological disposal management approach is more cost-effective than the other two management approaches. While the preliminary cost estimates for all three methods are generally similar, over the long term deep geological disposal is more cost-effective since it avoids the ongoing maintenance, monitoring and administrative costs associated with the long-term storage options. For this method, costs are relatively well known and time limited. Funding of the approach would not require the establishment of trust funds designed to be available for thousands of years, as would the storage approaches. Therefore, with this option financial surety is greater.

Many participants suggested that "proper siting" of a deep geologic facility would involve a remote location, which would remove the used nuclear fuel from large population centres. As with the centralized storage method, there is an opportunity to select a site that would maximize economic and human benefits, and involve impacted communities in site selection and facility design.

Limitations of the Approach

Overall, the limitations of this approach as seen by participants, focus on the need to transport waste potentially long distances and on the fact that because the method is designed to ensure the waste is sealed and isolated it is relatively more difficult to monitor and retrieve the waste.

Transportation was a focus of discussion. For many participants, transportation of the used fuel, whether by road, rail or water, was viewed as a very significant limitation of this management approach. For some participants, transportation related risk was considered to be so significant that this alone should make deep geological disposal and centralized storage unacceptable. Participants expressed concern about the potential for radiation exposure and/or surface and ground-water contamination due to a transportation related accident or spill.

Many participants suggested that maintenance of road and rail facilities in rural and northern areas would be a concern. If roads were not well maintained, this could increase the potential for accidents. Concern was also expressed about whether or not there would be adequate emergency preparedness and response personnel and equipment to respond to any accident or spill in rural and northern areas.

Many participants also expressed concern that the transportation of used nuclear fuel would offer an easy target for terrorists who wanted to sabotage or attempt to acquire the used fuel for some undesirable purpose.

As part of the conversation on this issue, some participants in the dialogues raised an alternative perspective for considering the transportation issue that some other participants found helpful. The suggestion was that the risk of moving used fuel, and its potential to cause harm in the event of an accident or sabotage, needed to be placed into context. In particular, the risk associated with the transportation of used fuel should be compared to experience in the management of other dangerous goods that are transported daily across this country. Such a comparison, it was suggested, would demonstrate that the transportation of this material, with appropriate equipment, procedures and emergency preparedness and response programs in place, offered minimal real risk and may well have less risk than the transport of other dangerous materials that occur on a regular basis.

Participants suggested that it might be difficult to win the support of surrounding communities for any site that is selected as well as communities along transportation routes. Some suggested there is a risk of widespread public protest and municipal opposition which may make it difficult to develop and implement either a deep geological disposal or centralized storage management approach.

Some participants expressed concern about the safety of the facility itself. As a first of a kind project, there is no definitive proof that the concept will perform as promised. These participants suggested there is no location at which this method has yet been implemented and demonstrated to work. For some participants, even the current deep geologic initiatives in Sweden and Finland were not considered as sufficient proof of concept. They were concerned that if an accident or breach does occur, it would be difficult, perhaps impossible, to take the necessary action to contain radioactivity. Furthermore, monitoring of the performance of the method would be difficult and unreliable. It might not be possible to detect and correct any problems within the repository in time.

Some participants suggested that since one cannot guarantee the long-term safety, committing to this management approach as the final fate for the used fuel would be an irresponsible action. Because long-term safety is unknown, future generations may be placed at risk and left a significant financial and management burden.

Some participants took issue with the deep geological disposal approach in that sealing away the used nuclear fuel would deprive future generations of the opportunity to use the remaining energy within the fuel rods, and take advantage of new technologies to make the used fuel safe and secure. The retrieval of this material from a deep geological disposal facility is expected to be costly and potentially risky from a health and safety perspective.

Some also felt that this method is irresponsible because it reflects an inappropriate “out of sight, out of mind” attitude. Storing the waste on the surface, on the other hand, symbolizes our explicit duty to take care of the waste we have created. Similarly, for some the lack of a requirement for institutional control is a disadvantage of this approach because attention on the facility may diminish over time and with this a decline in institutional vigilance.

Some participants suggested that it is misleading to believe that the number of sites in which used nuclear fuel is stored will be reduced, at least in the short term. Since the used fuel will still need to be stored at the seven sites for a period of time before it can be moved, the development of a deep geological disposal or centralized storage facility will mean that Canada would have eight locations containing used fuel, one more than the seven required for the storage at reactor sites approach. This additional site, some argue, increases the potential risk.

Participants in locations removed from the reactor sites, particularly some of the participants attending discussion sessions in northern Ontario, opposed the deep geological disposal management approach on the basis of fairness. These participants stated that the reactor communities, which have received the economic benefits of nuclear power generation, should now bear the responsibility for the care and management of the used fuel. To site a disposal facility in northern Ontario, which some suspect would be the likely location for a deep geological disposal facility on the Canadian Shield, it is argued would be unfair because these communities have not received any direct benefits from nuclear power. For similar reasons residents of Arctic areas, particularly the Inuit, are opposed to storing or transporting nuclear waste in the Arctic. Many participants, across Canada recognized the potential for economic, social and cultural unfairness should a northern community end up hosting a management facility. Many called for careful assessment of these implications and the collaborative development of a plan and an agreement to address them.

Finally, some participants in the Aboriginal dialogues opposed this option on the basis of their past experiences with buried chemical wastes that had leaked into the environment.

Option 2: Storage at Nuclear Reactor Sites

The management approach is:

- Long-term management of used nuclear fuel in storage facilities, at or just below surface, at each nuclear reactor site in Canada; and
- Storage facilities are maintained, rebuilt and operated in perpetuity at each reactor site.

Strengths of the Approach

Overall, the strength of this approach, as seen by participants, focuses on an understanding that this technology exists today, it involves minimal transportation, and it allows the used fuel to be easily accessed and monitored.

Most participants in our dialogues felt strongly that regardless of the management approach that is selected, it must allow the potential for future generations to have access to the used fuel. Some of these participants favoured easy accessibility so that future generations could use the used fuel as an energy source. Others expressed faith in technological advancement producing new technologies that will neutralize the used fuel and render it harmless. For those holding either view, storage at the reactor sites offered an advantage over the two other management approaches. Many suggested that since we don't know the solutions that may be developed in the future, there is still much to learn regarding nuclear energy technology. Making a final decision as to the fate of the used fuel should be deferred for a reasonable period of time. If the used fuel were to be used in the future for either purpose, then storage of some type would be preferred to final disposal.

Similarly, many commented on the "flexibility" of the option as an advantage. The approach is seen to be the most flexible of the three because the used nuclear fuel is easily accessible.

A significant advantage cited by most participants is that there is no need to transport the used fuel to another location. Many participants expressed concern about the risks of transporting used fuel. For them, the potential for exposure to radiation from any transportation accident is a significant limitation of the other two management approaches. The fact that this approach would require no off-site transport is therefore viewed as a major advantage.

Some argued that existing storage facilities at the reactor sites have been proven to be safe with little potential to cause harm to people or the environment. Further, the reactor site communities have considerable familiarity and experience with all aspects of the nuclear industry. As a result, the community will likely be less concerned or fearful of the long-term storage of this material and therefore may be more likely or willing to accept this management approach.

Some participants also considered this approach to be fair in that there is no need to determine a location for the management facility. Some commented that the reactor communities have benefited from the operation of the nuclear power plants through jobs and other economic and community benefits. It was suggested that it would only be right that those communities also take on the burden of caring for and managing the used fuel. Some also commented that these communities, because of the presence of nuclear power plants, possess knowledgeable and competent management, scientific and security expertise that will be available to provide the high levels of oversight necessary to ensure the safety of the used nuclear fuel.

Because storage is on the surface, many suggested it has the advantage of being easier to monitor. It provides more certainty in terms of knowledge because the technology is well understood. And as well, the environmental characteristics of the existing sites are well known.

Some also suggested that since "it doesn't put all eggs in one basket" if there is an environmental problem it would be easier to fix the individual site affected. In this way it is seen to be a method with greater adaptability.

Some participants in the Aboriginal dialogues favoured long-term storage at reactor sites, provided that waste be stored near population centres rather than in a "remote" location in order to ensure continued attention.

Limitations of the Approach

Overall, the limitations of this approach, as seen by participants, focus on the active management role that future generations would be expected to perform, and the uncertainty that these future generations would be willing or able to do so. Fairness is also a concern to the extent that existing host communities did not agree to long-term management when these facilities were sited.

Many participants expressed the view that the long-term storage of used fuel at the reactor sites was impractical. While it was suggested that short-term storage for the next 50 to 100 years might be acceptable, committing to this management approach for a period of thousands of years did not make sense. For this management approach to succeed, one needs to assume that future generations would be willing to take on the responsibility for oversight, monitoring and maintenance. For many participants, this was considered to be a highly questionable assumption.

Some participants felt that the costs for this management approach are too open-ended and therefore potentially excessive. In the event that future technological solutions do not materialize, the ongoing costs to manage the used fuel may become too much for future society to bear. The pressure to reduce funding for the maintenance of this management approach or to redirect funding to other priorities were considered to be real possibilities, which in turn would undermine the long-term safety of the management approach.

Contrary to the optimistic views expressed by some participants that future societies will thrive and technology will offer potential for more acceptable used fuel management solutions, some participants offered a pessimistic view. In particular, participants cited potential political and social instability and change as significant limitations of this approach. It was suggested that history is full of examples of civilizations that have either disappeared or significantly changed over time. Our current form of government, economic and social institutions cannot be guaranteed to exist for several hundreds not to mention thousands of years. Because of this uncertainty, many felt that it would be irresponsible to not determine a final solution for the management of the used fuel. Leaving used fuel in storage over the long-term could well place both people and the environment at risk.

Some participants felt that the selection of this approach would be an abdication of our responsibility to take the necessary action to properly manage the used fuel. In their view, selecting this approach would be "not making a decision" since the final decision would be deferred to the future.

Some suggested that because this management approach would mean that there would be multiple storage sites, the potential exists for the uneven application of procedures and risk management measures across the sites. This might compromise the safety of storage facilities. In effect, participants said that the more sites that require management, the greater the potential for error or breach. Due to the multiple sites, it may also be more difficult to assure security.

Some participants also noted that the reactor sites are all located on bodies of water that serve as sources of drinking water, recreation and economic opportunities. The development of long-term storage facilities in close proximity to these water bodies represents an additional potential risk to people and the environment. In the very long term, sites adjacent to tidal water may be vulnerable if sea level rise occurs.

Finally, some participants commented that the initial siting decision for nuclear power plants and the acceptance of those communities did not extend to these sites being used for long-term storage of used nuclear fuel. Some participants felt that these locations did not offer the appropriate conditions for long-term management of used fuel. Requiring these communities to continue to store the used fuel over the long term would be unfair.

Option 3: Centralized Storage

The management approach is:

- Long-term management of used nuclear fuel in a storage facility, above or just below ground, at a central site in Canada;
- Used nuclear fuel is transported from the nuclear reactor sites to the central location for long-term management; and
- The storage facility is maintained, rebuilt and operated in perpetuity at this central site.

Strengths of the Approach

Overall, the strengths of this approach, as identified by participants, are similar in some respects to those raised concerning long-term storage at reactor sites, and deep geological disposal.

One of the significant advantages identified with this approach, similar to deep geological disposal, is that used nuclear fuel would be removed from the existing reactor sites and put in a single location, specifically selected and built for the purpose of long-term storage. A single location would be easier to monitor and, particularly if built below the surface, would be more secure than multiple sites. It would also be more cost efficient.

Many participants suggested that, similar to deep geological disposal, an advantage of this approach is the opportunity to remove the used nuclear fuel from population centres and to a more remote location.

As with the deep geological disposal approach, the development of a centralized storage facility offers the potential for jobs, investments, purchasing of goods and supplies, and other economic benefits to residents, businesses and municipal governments who might be involved in the new facility.

The siting of a centralized storage facility, many participants suggested, may be easier than the siting of a facility for deep geological disposal because this approach does not rely on the geological conditions of a site in order to contain and isolate the used nuclear fuel. When compared to deep geological disposal, which would require highly specific siting requirements, centralized storage could be established in many different settings.

Because of this potential siting flexibility, some participants felt that the chances of there being a willing host community for the centralized storage facility would be greater than for a deep geological facility. Some suggested that the facility might also be located in an area that had clearly enjoyed the benefits of nuclear power, which would make such a siting decision fairer.

As with storage at the reactor sites, centralized storage would meet the preference of many participants for a management approach that is flexible, and that can adapt to new knowledge and events. With this approach, there would be no final fate decision; the stored used fuel would be accessible and retrievable either to take advantage of new nuclear waste management technologies or for future use as an energy source.

The used nuclear fuel would also be easily monitored. From the perspective of some participants, an advantage of this approach is also that it keeps the used fuel visible. In addition to this visibility, the requirement for on-going attention and care would therefore allow future generations to actively manage the material to ensure safety, and would ensure high standards of management and monitoring are maintained over time. It would also serve as an incentive to spur research into emerging technologies for the future management of the used fuel.

Limitations of the Approach

Overall, the limitations of this approach, as identified by participants, are similar in some respects to those raised concerning both long-term storage at reactor sites and deep geological disposal.

This approach, like reactor site storage, requires future generations to maintain the commitment to manage, and care for the used fuel. Some participants repeated their skepticism that future generations would continue to fund and manage the used fuel. They believe the ongoing commitment to the approach cannot be guaranteed over time. The stability of future society, government institutions, and societal values and priorities are highly questionable.

The continued and periodic repackaging required by this approach was suggested as presenting an increased health and safety risk to workers, and to the public at large should there be a lapse in diligence.

As an above ground facility, the approach is considered to be more vulnerable to security threats. It is also more vulnerable to the long-term implications of climate change, and glaciation.

For those participants who feel there is an urgent need to develop a final solution for the management of the used fuel, this management approach possesses the same drawbacks as the reactor site storage approach. Considering the long time period over which the used fuel would remain a hazard to people and the environment, this management approach does not provide the final solution which some participants seek. Rather, this approach "defers to the future" final decisions about how the used fuel will be managed. Integral to this is the potential that the siting decision would need to be made twice, thereby doubling any unfairness in the siting process. Lack of action on a final solution by our generation "would be irresponsible."

Many participants wondered whether a willing host community could be found to accept a centralized storage facility. Even if a community did express a willingness to accept a facility, it was felt that surrounding areas and communities along transportation routes are likely to be less willing or would even be opposed.

Many participants expressed concerns about the transportation of the used fuel to a centralized storage location. Many communities along a transportation route could be affected. Public anxiety over risks associated with transportation may make it difficult or impossible to implement the approach.

Finally, some participants felt that this management approach might represent the greatest potential for risk to people and the environment of the three management approaches. By bringing all the used fuel to one central location, the potential impact from a catastrophic event (terrorism, sabotage or meteor strike) would be much greater than any comparable event at a facility managing less used fuel, or with deep geological disposal. In this regard, if centralized storage was selected, most participants favoured shallow burial of the storage facility over surface storage for this reason.

3.4 / Striking the Right Balance

As participants described to us advantages and limitations for each of the approaches under study, they also recognized that deciding among the approaches would be difficult. This is because no one of the approaches meets all the values and objectives that had been identified as important for a management approach for Canada. They identified which aspects of the decision required a difficult choice.

Balancing Security with Accessibility

Some participants argued for the importance of sealing used nuclear fuel underground, as the deep geological disposal approach would provide the best means of achieving safety and security. The used nuclear fuel would be more effectively isolated from people and the environment, and it would also be more secure in the face of human intrusion. However, it makes retrieving and monitoring that waste difficult.

A number of participants argued for the importance of keeping the waste accessible, which is a feature of the storage approaches. Accessibility makes it easy to monitor the waste, and quickly take corrective action should a problem occur. It allows for implementation of new technologies for the management of the waste or access if a new use for the waste be found. However, this accessibility would make keeping the waste secure more difficult.

Choosing among the methods, involves choosing between maximizing security or maximizing accessibility to the used nuclear fuel.

Balancing the Minimization of Transportation with the Removal of Used Fuel from Population Centres

Many participants expressed concern about the prospect of transporting used nuclear fuel. For many, an important limitation of the centralized storage approach and the deep disposal approach is the requirement that used nuclear fuel be transported, potentially for substantial distances, to the site. They expressed concern that an accident may result in the release of radioactive material, and thereby pose a risk to the health of people and the environment. Concern was also expressed that transport shipments may pose a target for terrorists. Concern about transportation of used nuclear fuel was expressed in all dialogues and all parts of the country. It was also a particular area of concern raised by Aboriginal People.

Many of the same participants also expressed concern about storing used nuclear fuel over the long term near large population centres, as the reactor site storage approach would involve. For these participants, an important advantage of the centralized storage approach and the deep geological disposal approach is the opportunity to remove the waste from current reactor sites to a more remote location, away from population centres.

Some Canadians feel used nuclear fuel should be removed from population centres, while others would like to see handling and transportation of the waste be minimized to reduce possibility of accident. An additional challenge is to allow for the inevitable migration of population over the very long period of time involved.

Choosing among the methods, involves choosing between minimizing the transport of used fuel and maximizing the remoteness of any waste management facility.

Balancing the Taking of a Decision Today with Providing Flexibility for Future Generations

Most participants told us they feel strongly that the generation which enjoyed the benefits should implement a solution and not transfer this problem to future generations. Some of these participants argued that we have the knowledge and capacity today to put in place a definitive solution, a solution that would relieve the burden of managing this waste from future generations. It would be irresponsible not to take this definitive action now, they said.

Other participants argued that the action we take today should not preclude future generations making their own decisions. Although we have much knowledge today, continued research may surface new or better options in the future. It would be irresponsible to put in place a management approach today which precluded future generations from taking advantage of what will "inevitably" be new learning in the future.

Choosing among the methods, involves choosing between implementing a definitive solution today or building in flexibility to allow future generations to influence the way in which the material is managed.

Balancing Fairness to Current Host Communities with Fairness to Future Host Communities

Over the course of the dialogues participants wrestled with the issue of fairness concerning the siting of any facility which may ultimately be required. Many participants expressed the perspective that it would be unfair to expect a community that had not received any benefit from nuclear energy to become the site of a long-term waste management facility. Many participants also expressed the perspective that although current reactor site communities may have received the greatest benefit from nuclear energy, they should not be expected to host a long-term management facility because it goes beyond the terms of their original agreement to host the existing interim management facility.

Participants in the Aboriginal Dialogues, as well as other participants living in northern areas, articulated similar concerns in saying that locating a facility in the "north" would be unfair given that few benefits have accrued to them.

Choosing among the methods, involves balancing consideration of the fairness to current host communities with consideration of the fairness to future host communities.

3.5 / Expanding the Options

After looking at the strengths and weaknesses of each of the options individually, many participants suggested that an 'obvious' additional approach be considered, one that builds on the advantages of the various approaches. These participants variably referred to this hybrid approach as: centralized storage at a long-term geologically suitable location, fully retrievable deep geologic disposal, convertible geological storage, underground centralized storage, and, centralized storage at a deep geologic disposal site.

The hybrid approaches suggested tend to share the following characteristics:

- A period of extended storage of used fuel at the reactor sites, for a definite period of time. The waste is currently safely stored in these facilities, and would continue to be so for some time to come;
- Consolidating the used fuel at one central location, on the surface or in shallow underground storage as a preliminary step;
- A period of learning. Emerging technologies may offer potential to either neutralize the radionuclides in the used fuel or allow for the safe and cost-effective reuse of the waste. It would also allow us to learn from the experience of other countries that are in the process of implementing long-term used fuel management approaches. In addition, there may be greater certainty about the future of nuclear power in Canada;
- Development of a deep geologic repository either to be used for deep underground centralized storage or as final disposal, if needed;
- A period of relatively easy access and retrievability; and
- Staged decision-making. After a definite period of time, decide whether to continue to store the used fuel at the surface or shallow underground, or whether and when to place it in a deep geological storage or disposal facility.

Hybrid approaches tended to be a focus of discussion among participants who see value in the management approach being both flexible and adaptable, and ultimately definitive.

Participants who see less value in adaptability were less likely to suggest such a hybrid approach. As discussed earlier, some participants expressed the view that prompt implementation of the deep geological disposal approach would best ensure the safe management of the used nuclear fuel, and additional research is unlikely to surface better management approaches or new uses for the fuel. Participants with this view were more likely to see a hybrid approach as potentially introducing unnecessary delays, uncertainty and costs in implementation.

3.6 / An Appropriate Implementation Plan

Throughout the dialogues, participants talked to us about the type of implementation plan that should accompany any management approach selected. They recognized that the decision-making and implementation processes for Canada's used nuclear fuel will involve at least many decades. They said it will be important that a management approach be implemented in a way that continues to be responsive to the values and objectives of Canadians.

We heard from dialogue participants that any management approach for Canada should have the following characteristics:

- Begin the initial steps toward implementation now;
- Ensure that safety for people and the environment is the primary consideration, including security and safeguards performance;
- Ensure implementation in as fair a way as possible;
- Accommodate new learning;
- Provide for a staged approach that provides for ongoing reviews and adjustments to decisions;
- Provide opportunities for future generations to influence the implementation;
- Prepare future generations for their responsibilities;
- Monitor emerging research and technical developments in Canada and internationally, including opportunities to reduce the inherent hazard associated with used nuclear fuel;
- Communicate clearly the decision-making process and authorities;
- Ensure that the system of governance combined with the capacity to deliver is trustworthy, accountable and inclusive;
- Involve democratic and accountable institutions, accessible to citizens;
- Ensure that citizens are informed, and have a voice at each stage in the process;
- Engage and understand concerns of regions and communities that are affected directly and indirectly;
- Build a good understanding of potential risks and the means to manage them, including those related to transportation;
- Include a "community commitments" plan that would include monitoring, economic benefits and property value protection agreements for any host community. This should be established before beginning siting of any facility;
- Develop contingency plans including those for emergencies. In addition to ensuring that all communities have trained personnel, ensure equipment and financial resources to support all emergency response in the host community and along transportation routes;
- Provide surety that sufficient funds will be secured and protected, available to fund the long-term management approach selected by government;
- Ensure that the amount of money spent is commensurate with the risk this material poses vis-à-vis other problems our society needs to address;
- Develop a monitoring program, which encompasses quality control and quality assurance standards in collaboration with impacted communities; and
- Be sensitive to the broader and dynamic policy context.

3.7 / NWMO Observations

The question of what constitutes 'responsible action' in the long-term management of used nuclear fuel has been central to the complex and, at some times, impassioned discussion we have had with Canadians. We have heard participants in our dialogues propose values and objectives to guide our decision-making and serve as a platform for moving forward. As a true product of collaborative development, these values and objectives reflect the common ground of individuals and groups with many diverse perspectives on this issue. They suggest the terms and conditions of a collective journey to implement a long-term management approach for Canada which acknowledges both the areas in which we all agree and are prepared to proceed quickly and the areas in which greater confidence needs to be gained before proceeding.

We have heard that people wish to proceed. In fact, they expect to immediately begin the process of implementing a long-term management approach for Canada. While some are very comfortable to move quickly to implement a final or definitive solution, we have heard from others they are only prepared to proceed with caution. These people would like the opportunity to learn more, understand better, and build greater confidence in decisions before they are taken, particularly if these decisions are difficult to reverse.

We believe that the evidence of common ground that has emerged from the dialogues provides the foundation for a staged and adaptive approach to be taken. This should be an approach which has a clear direction and end in mind, but which has built in to it flexibility to further explore the areas where citizens wish to gain greater confidence. At each point in the process, the safety of people and the environment needs to be assured, and contingency plans need to be put in place. A clear and appropriate decision-making process needs to guide the journey, and strong and independent oversight needs to help ensure that we continue to progress towards our goal. It is this understanding, and the detailed guidance from dialogue participants as highlighted in this chapter, which forms the foundation for our recommended approach.

In Part Three of this report, we outline how we have used the direction that has emerged from the dialogue in the assessment of the management approaches in the design of an additional management approach for consideration.

PART THREE Assessment of Management Options

CHAPTER 4 / COMPARISON OF BENEFITS, RISKS AND COSTS

Nuclear Fuel Waste Act (*NFWA*) reference:
12. (4) Each proposed approach must include a comparison of the benefits, risks and costs of that approach with those of the other approaches, taking into account the economic region in which that approach would be implemented, as well as ethical, social and economic considerations associated with that approach.

Section 12(4) of the *Nuclear Fuel Waste Act* (*NFWA*) outlines the comparative assessment that the NWMO must undertake in considering the different management approaches.

Section 4.1 describes the steps taken to develop the assessment framework within which we assessed the management approaches.

Section 4.2 describes the systematic streams of analysis that we applied in examining the costs, benefits and risks of the management approaches.

Section 4.3 reports on the results of our assessment.

In Part Two, we outlined the broad direction which emerged from citizens. We reviewed the process by which this broad direction was iteratively confirmed through the NWMO's first and second discussion documents. And, we described how we engaged a broad range of experts in assembling the information to inform the assessment.

In this section of the report, we highlight the major exercises which the NWMO used to:

- Translate the direction of citizens into a concrete framework which could be used for the assessment, and
- Then to apply this framework to assess the used fuel management options.

We conclude this chapter with a summary of the NWMO's assessment of the management approaches against the framework.

4.1 / Study Foundations: The Building of an Assessment Framework

One of our first tasks was to find a way of assessing the management approaches.

We wanted our assessment of the options to be guided by the values and expectations of Canadians in general, and by technical experts.

We adopted sustainable development as the conceptual underpinning for the assessment of management approaches. We committed to "develop collaboratively with Canadians a management approach for the long-term care of used nuclear fuel that is socially acceptable, technically sound, environmentally responsible and economically feasible."

The pillars of sustainable development capture the range of issues identified in our early conversations with Canadians, and our belief that our recommendation to Government cannot lie in science and technology alone. It must also be rooted in broader social and ethical dimensions. Our framework for judging options was designed to integrate these different dimensions.

In our early conversations, stakeholders communicated an interest in contributing to our thinking, not just in responding to a final report. We were asked to approach the study in manageable steps that would encourage citizens to think about complex issues, and provide informed, thoughtful feedback. We therefore approached our assessment in phases, to allow information, analyses and thinking to be shared and considered publicly in a staged manner. The nature of the comments and learning from public engagement have continued to shape the study. This interplay between public engagement and expert analysis began in 2002 and will continue through to the completion of the study in 2005.

We conducted an extensive process of public engagement with the general public and with Aboriginal Peoples, which we report on in Part Two.

We convened a dialogue on fundamental values and ethics.

- We led a National Citizens' Dialogue, drawing from a cross-section of the Canadian public, to explore the key values that should be reflected in the assessment;

- We convened a workshop to explore how Traditional Aboriginal Wisdom and Knowledge might be brought to bear on the set of issues faced by the NWMO;

- We established a Roundtable on Ethics to provide guidance on an ethical and social framework to guide our assessment of options; and

- Through a number of major engagement initiatives with Canadians, we developed and confirmed the key questions and objectives that formed the basis of our assessment as we examined the options.

  > The eight objectives are: fairness; public health and safety; worker health and safety; community well-being; security; environmental integrity; economic viability; and adaptability;

  > The citizen values are: first and foremost, safety from harm; responsibility; adaptability; stewardship; accountability and transparency; knowledge; and inclusion; and

  > The ethical principles are: respect for life; respect for future generations; respect for people and cultures; justice; fairness; sensitivity to differences in values and interpretation.

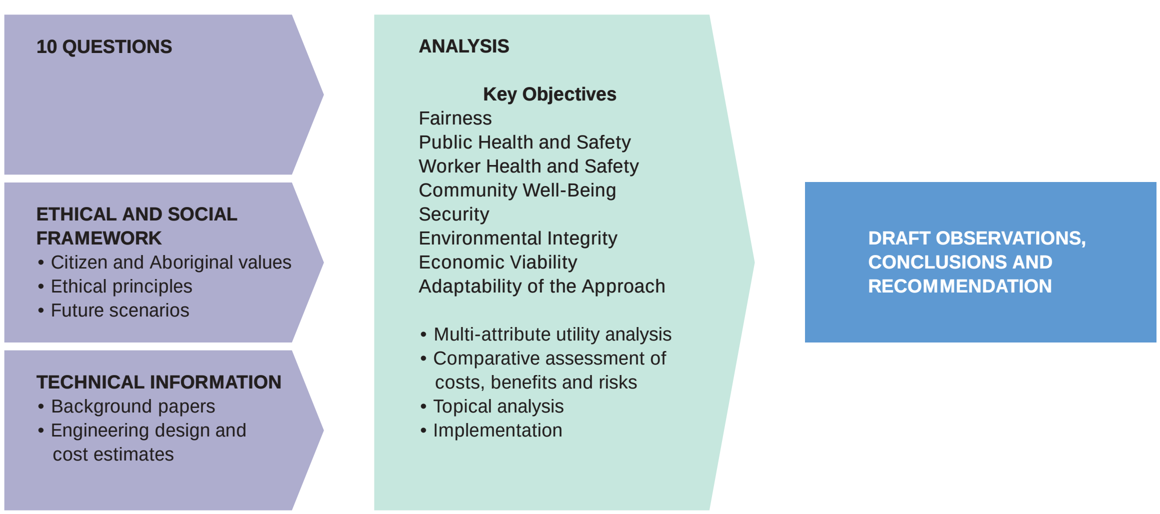
We synthesized and considered a vast body of accumulated information on technical, social, environmental and financial considerations.

- Our analytical work was informed by a number of commissioned background papers and workshops that enabled us to address a wide range of topics in detail. In total, we have commissioned over 60 background papers to support our study. We engaged more than 110 scientific and technical advisors, and more than 90 advisors on governance, institutional and legal matters. As well, we engaged more than 200 knowledge experts in public policy issues, Traditional Knowledge and social sciences. A listing of these background papers and reports from workshops are provided in Appendix 4.

We reviewed the range of potential management options, and selected those that would become the focus of our initial study: Deep Geological Disposal in the Canadian Shield; Storage at Nuclear Reactor Sites; and Centralized Storage.

Once the foundations for our assessment were laid, we subjected the options to multiple analytical processes. In Section 4.2, we outline these processes.

Figure 3-1 NWMO Assessment of Management Approaches



4.2 / Understanding the Choices

The assessment of the management approaches required a series of exercises that assessed the options against eight objectives, and brought different and important perspectives to the analysis of costs, benefits and risks. We commissioned different, separate and complementary assessments to complete our understanding of the costs, benefits and risks. They ranged from the conventional cost-benefit analyses, to scenario building and multi-attribute utility analyses. All of this work was supported and enhanced by research papers commissioned by the NWMO, submissions and papers made available to the organization, and by the broader public dialogue that continued to unfold.

Following is a summary of different activities that were at the core of our assessment of management approaches.

Multi-Attribute Utility Analysis: Testing the Options Against Multiple Goals

We brought together a group of individuals to work as an Assessment Team. These individuals were chosen for their diverse experiences and complementary skills in addressing complex public policy issues. Their skills ranged from environmental assessment and risk management to economic, financial and social policy analysis.

The team tackled a range of social, technical, environmental and economic aspects of used nuclear fuel management. They translated the 10 questions identified early in our work into a formal assessment framework that features eight objectives and a list of specific influencing factors based on the values and direction of Canadians identified through our engagement activities.

We asked our Assessment Team to develop a rigorous methodology for the assessment of management approaches. We then asked them to apply that assessment framework to the three options in the *NFWA*.

Consistent with the framework outlined in our first discussion document, the team selected a methodology that would allow for the integration of social and ethical objectives and principles, along with technical, economic, financial and environmental considerations.

The choice of the methodology was guided by the goals described above and influenced by a need to explicitly address multiple objectives in developing Canada's approach for dealing with used nuclear fuel. These multiple objectives are clearly demonstrated in our first discussion document, *Asking the Right Questions? The Future Management of Canada's Used Nuclear Fuel*. The 10 questions listed in that report cover a broad range of objectives, including the maintenance of public health and safety, environmental integrity, ensuring human health and safety, and maintaining security. Because of these multiple objectives, attention was restricted to a class of assessment methodologies known as "multi-objective" or "multi-criteria" decision tools. These tools are distinguished by their capacity to explicitly represent and work with such multiple objectives.

From the sub-group of "multi-criteria" decision tools, the methodology known as multi-attribute utility analysis (MUA) was selected. This tool was selected for its ability to aid in discriminating among the options through transparent deliberation. Multi-attribute utility analysis provides a step-by-step process for constructing and applying a decision model. It can be used to help identify a most preferred option, to rank options, to screen options down to a short list for more detailed analysis, or to distinguish acceptable from unacceptable choices. Many technical requirements (governing scoring, scaling, weighting, and aggregating) must be satisfied to ensure that quantitative rankings produced by the model logically flow from the judgments of the Assessment Team. The long experience and evolved theory together provided a strong basis for the selection of this methodology.

Over the past two decades, numerous applications of multi-attribute utility analysis have been conducted in Canada, Great Britain, the United States and in many other countries, to assist decision-making in both the private and public sectors. A key characteristic of multi-attribute utility analysis (as well as other multi-objective approaches) is its emphasis on the judgments of the decision-making team that the analysis is intended to serve. The fact that multi-attribute utility analysis makes those judgments open and explicit was considered a strong advantage. Since the judgments and assumptions are represented as inputs to a decision model, interested parties can explore whether changes would alter conclusions.

The framework features eight objectives:

- Fairness
- Public health and safety
- Worker health and safety
- Security
- Economic viability
- Community well-being
- Environmental integrity
- Adaptability.

For each objective, the factors that may influence the capacity to perform well against the objective were identified and mapped. The resulting "influence diagrams" created for each of the eight objectives, acted as a road map for our assessment. The focus of this analysis was on the objectives and factors that distinguished the management options from one another.

The team recognized that the management of used nuclear fuel must consider both a short and long-term perspective. Used nuclear fuel has the potential to affect humans and the environment for a very long period, likely hundreds of thousands of years or longer. No assessment of benefits, risks and costs can be complete without considering a range of time periods. Two time periods were used by the team for evaluating options:

Near Term, which was defined as 1 to 175 years.

- The 175-year time horizon coincides with the seven generations concept that emerged from Aboriginal Traditional Wisdom as a target time horizon that we should use when considering the implications of today's decisions;

- It also coincides with the period during which site identification, development, licencing, operation and closure of a repository would occur. It represents a reasonable dividing line between the active period and the long-term, follow-on period;

- From a societal perspective, it is reasonable to assume the continuity of current institutional and economic structures and activities during this period;

- From a technical perspective, this time horizon marks the limit to which engineering predictions and the characteristics of human-made objects can be reasonably forecast. During such a period, environmental conditions, although undoubtedly changing, can be reasonably assumed to maintain some similarity to those of today; and

- From a scientific perspective, a period of about 175 years marks a defensible and fairly distinct division in the nature of the hazard to humans and biological life posed by nuclear fuel waste. It is the period when the used fuel bundles have been out of reactor for about 50 years and will have cooled to near-ambient temperatures. By about this time, the short-lived radioisotopes, including many of the highly dangerous ones that account for most of the radioactivity contained in the waste when it is first removed from the reactor, will have decayed to insignificant levels. What will remain is the hazard from long half-life elements and isotopes that are present in much smaller quantities but remain dangerous for a very long time. During a 175-year period, the overall radioactivity of used fuel drops to about one-billionth of the level when it was removed from the reactors, but still poses a significant long-term hazard.

Long Term, which was defined as greater than 175 years.

- In this time period, Aboriginal wisdom and future scenarios work conducted by the NWMO both suggest it is not prudent to assume that social, institutional, or environmental conditions will closely resemble those of today;

- Although it is possible to predict the geological characteristics of rock with some confidence, the vagaries of environmental conditions above ground, combined with human-induced or natural stresses on the environment make any assessment of the human-ecological interactions extremely speculative; and

- The radioactivity of nuclear fuel wastes will continue to decline, but isotopes of chlorine, caesium, strontium and plutonium will remain radioactive and continue to pose health risks that continue to decline over time.

Three management options for used nuclear fuel were assessed using the framework. Note that the description of the management approaches was taken from conceptual engineering designs and cost estimates prepared by the Joint Waste Owners. The multi-disciplinary group of individuals, who comprised the Assessment Team, did not assess each of the management options on the objectives in precisely the same way. In fact, the ranges in the scores for the three options assigned by team members was quite wide, in most cases. The broad range of scores on many objectives reflected differing views among members of the Assessment Team concerning future environmental and social conditions in Canada, as well as questions regarding how well the approaches might actually perform.

The work of the Assessment Team also involved the conduct of a sensitivity analysis. This analysis included the assessment of the management approaches against plausible future alternatives. These scenarios were identified as part of a major NWMO scenarios exercise earlier in the study. Additional scenarios were considered by NWMO and are described in Appendix 12.

Through this assessment, the Assessment Team began at the most conceptual level to articulate strengths and limitations of each approach, and present this material as a basis for public discussion.

This analysis found that no single option on its own perfectly met the objectives that Canadians said were important. The Assessment Team work brought into focus some of the difficult choices and trade-offs to be addressed as part of the assessment of the approaches.

The results of this assessment were published in our second discussion document in 2004, *Understanding the Choices* (www.nwmo.ca/understandingthechoices). In this document, we sought public review of this assessment framework, and we received comments that validated the appropriateness of the eight objectives. Accordingly, we adopted those objectives as the basis upon which we assessed the different management options. The full report of the Assessment Team is available at www.nwmo.ca/assessmentteamreport.

A Fourth Option Emerges

We reflected on the assessment of the three technical methods specified in the *NFWA*, and we listened to the commentary received from our engagement process with the general public and Aboriginal Peoples. As we did, a fourth option began to emerge.

The three methods that we studied are well understood and are technically credible and viable methods. Deep geological disposal is in an advanced state of scientific and technical understanding internationally. Used fuel storage technologies have been safely demonstrated for many years at reactor sites in Canada. However, as we listened to the public and Aboriginal Peoples and considered the findings of our research, we understood that the most profound challenge lies not in finding an appropriate technical method, but in the manner in which the management approach is implemented.

The fourth option – Adaptive Phased Management – emerged from our observations:

- Our belief is that there is a need for this generation to take responsible action now for planning the long-term management of used nuclear fuel. The technical methods available are well understood. With the information we have today, we must move forward responsibly to plan for the safe, secure isolation of used fuel for the very long term;

- Our understanding is that over the long time periods involved in implementation, we must anticipate that new learning and information could change the ongoing process of decision-making around implementation. The recommended management approach must have associated with it the necessary flexibility and adaptability that would support careful deliberation and decisions along the way. We can recommend the end point that we believe is the most desirable end state. We cannot prescribe in detail the timing and specific steps required to move toward the final step in implementation; and

- Our obligation is to provide true choice to future generations and opportunity to shape decisions in years to come. This means avoiding approaches that are irreversible; planning conservatively by setting aside the financial resources to ensure flexibility in future decisions; and respecting emerging science and committing to a continued watch on new technological developments and learning over time.

The fourth option is based on centralized containment and isolation of Canada's used nuclear fuel deep underground. There are three major phases for concept implementation, which are described for illustration purposes. Each of the three phases has a number of key activities and decision points. While we do not know the precise duration of these activities or the outcome of future decisions in the approach, we can provide an indication of a representative schedule for implementation based on the conceptual design work and previous analyses of the three options for used fuel management specified for study in the *NFWA*.

Comparative Assessment of Costs, Benefits, and Risks

We continued our work to carefully consider costs, benefits, and risks of all the options we considered, building on the multi-attribute utility analysis completed by our Assessment Team. We commissioned traditional cost, benefit and risk analysis by two consulting companies, Golder Associates Limited and Gartner Lee Limited.

The objective of the study was to develop and implement a methodology with which to undertake the comparative assessment of benefits, risks and costs of four management approaches, taking into account illustrative economic regions and grounded in the 10 key questions identified by Canadians.

Against the same eight objectives used by the Assessment Team, a comparison of the management approaches was undertaken on costs, benefits and on risks and uncertainty, looking at:

- Both near- and long-term time considerations; and
- Impacts of different site locations based on economic regions.

This comprehensive assessment of the benefits, risks and costs of the management approaches was conducted using the following steps:

- Design and development of methods and tools for assessing the benefits, risks and costs of alternative approaches to the management of used nuclear fuel in Canada;
- Identification and development of background information for "illustrative" economic regions that allowed a comparison of the benefits, risks and costs for each approach with those of other approaches, taking into account the economic region in which the approach could be implemented:
  - > We have not sought to select a specific site or single economic region for implementation of a management approach. However, to meet the requirements of the legislation, we had to consider how the costs and benefits and risks might be affected when one takes into account different types of economic regions;
  - > Economic regions selected for purposes of analysis covered a range of physical and socio-economic conditions, illustrative of different regions of the country; and

> Illustrative economic regions were chosen to highlight how approaches might perform in regions with different physical and socio-economic foundations. We looked at different population densities, different distributions of economic activity and differing transportation requirements associated with implementing an approach. This analysis was intended to highlight considerations that would arise in diverse economies, environments and population centres in an illustrative way for the analysis. It was not an attempt to pre-qualify or select sites for possible implementation.

- Examination of the numerous influencing factors for each of the eight objectives that were identified in the preliminary comparative assessment for further detailed analysis;

- Identification of measures and indicators for each of the influencing factors studied in detail for use in the comparative assessment. They were selected to allow the evaluation of the performance of the four approaches against each of the eight objectives, using quantitative measures for influencing factors where these are available and providing qualitative discussion on other influencing factors, where feasible;

- Analysis of each of the approaches across the applicable illustrative economic regions, using information from the chosen measures and indicators. In assessing the options, the assessment looked at possible impacts, the consequence of impacts and the likelihood and timing when such an event might occur;

- A comparative assessment of the benefits, risks and costs using information from the above analysis. The analysis developed and applied appropriate and proven models that are capable of estimating effects within the social and environmental framework of the assessment; and

- Assessment and comparison of the benefits, risks and costs of each approach with those of other approaches, taking into account the economic regions in which that approach would be implemented, as well as the ethical, social and economic considerations associated with that approach.

The starting point of the assessment was a review of the conceptual engineering designs for each of the management approaches and the cost estimates prepared for the Joint Waste Owners and accepted by the NWMO. A detailed financial model of each management approach was developed for the purpose of assessing their economic viability. These financial models describe the management phases and apply specific costs for labour and materials over a timeline extending out thousands of years. Financial models enabled the study team to test alternative costing assumptions.

The assessment of the community well-being objective was divided into two parts.

- First, economic relationships were modelled for 11 different illustrative economic regions (described in Section 9.2). A unique input-output model was developed for each economic region, which enabled the study team to consider impacts on employment, income and taxes from the possible introduction of any of the management approaches. In addition, a qualitative assessment of other community values was conducted based on a combination of published literature and the study team's own extensive experience with nuclear and mining industry developments in both urban and rural regions of Canada; and

- The second part of the community well-being assessment involved application of the "Sustainable Livelihoods Framework" to each of the 11 illustrative economic regions. This framework allows an objective assessment of specific "capitals" including social, human, physical, financial, and natural. The intent of this quantitative analysis was to provide an indication of how each economic region ranks in its ability to adapt to the opportunities and challenges posed by the introduction of any of the management approaches.

The analysis introduced further information on how each approach was expected to perform against the eight objectives. It contributed further qualitative insights, to help broaden our understanding of costs, benefits and risks. Importantly, it included socio-economic analysis of the implications for the different types of economic regions that might host the facilities. This allowed us to consider how the location of a facility or facilities might affect benefits, risks, and costs.

The detailed findings from this comparative assessment are available on our website. (www.nwmo.ca/assessments)

4.3 / Our Assessment Findings

As required in the *NFWA*, we have compared the benefits, risks and costs of each management approach, taking into account the economic regions in which that approach might be implemented, as well as ethical, social and economic considerations associated with that approach.

Section 4.3 presents the key findings from our comparative assessment as we examined each of the four options against the eight objectives we established for our study.

- We present the benefits and areas of risk and uncertainty that we examined against each of the eight objectives we established for our assessment; and

- We present a comparative discussion of costs for each management approach under the section on "Economic Viability."

The sources for our findings include numerous reports, background papers, dialogues and assessments conducted over our study of options, all of which are available on our website. What follows is our interpretation and conclusions of these reports, papers, dialogues and assessments. For some detailed discussion on the assessment of the options, readers are referred specifically to the following reports on our website:

> The Assessment Team report, www.nwmo.ca/assessmentteamreport
> The Golder/Gartner Lee technical report www.nwmo.ca/assessments
> The paper on risk and uncertainty (SENES) www.nwmo.ca/assessments
> Reports from our dialogue with Aboriginal Peoples and the general public. www.nwmo.ca/dialoguereports

In this section, we present our overall conclusions based on the comparative assessment of the four management approaches.

Fairness Analysis

Our objective:
To ensure fairness (in substance and process) in the distribution of costs, benefits, risks and responsibilities, within this generation and across generations.

The selected approach should produce a fair sharing of costs, benefits, risks and responsibilities, now and in the future. In addition, fairness means providing for the participation of interested citizens in key decisions through full and deliberate public engagement during different phases of decision-making and implementation.

In our assessment of fairness, we considered issues of both substantive and procedural fairness.

Substantive fairness includes consideration of how the costs and benefits associated with the approach would be distributed among different people and between humans and other species. It also includes consideration of intergenerational fairness. A key question for intergenerational fairness is the balance struck between the desire that the current generation take responsibility for resolving the problem once-and-for-all versus the desire not to overly constrain future generations by the choices we make today.

Procedural fairness is mainly a function of the degree to which the approach would allow for the participation of concerned citizens in key decisions about how the approach would be implemented. This, in turn, depends in part on the opportunities for decision-making provided by the approach and the availability of information that would be helpful for driving those decisions.

The complete list of influences considered is identified in the diagram below.

Comparative Assessment

Table 3-1 presents our assessment of the relative benefits and risks and uncertainty for each of the four options studied.

Figure 3-2 Fairness Influence Diagram

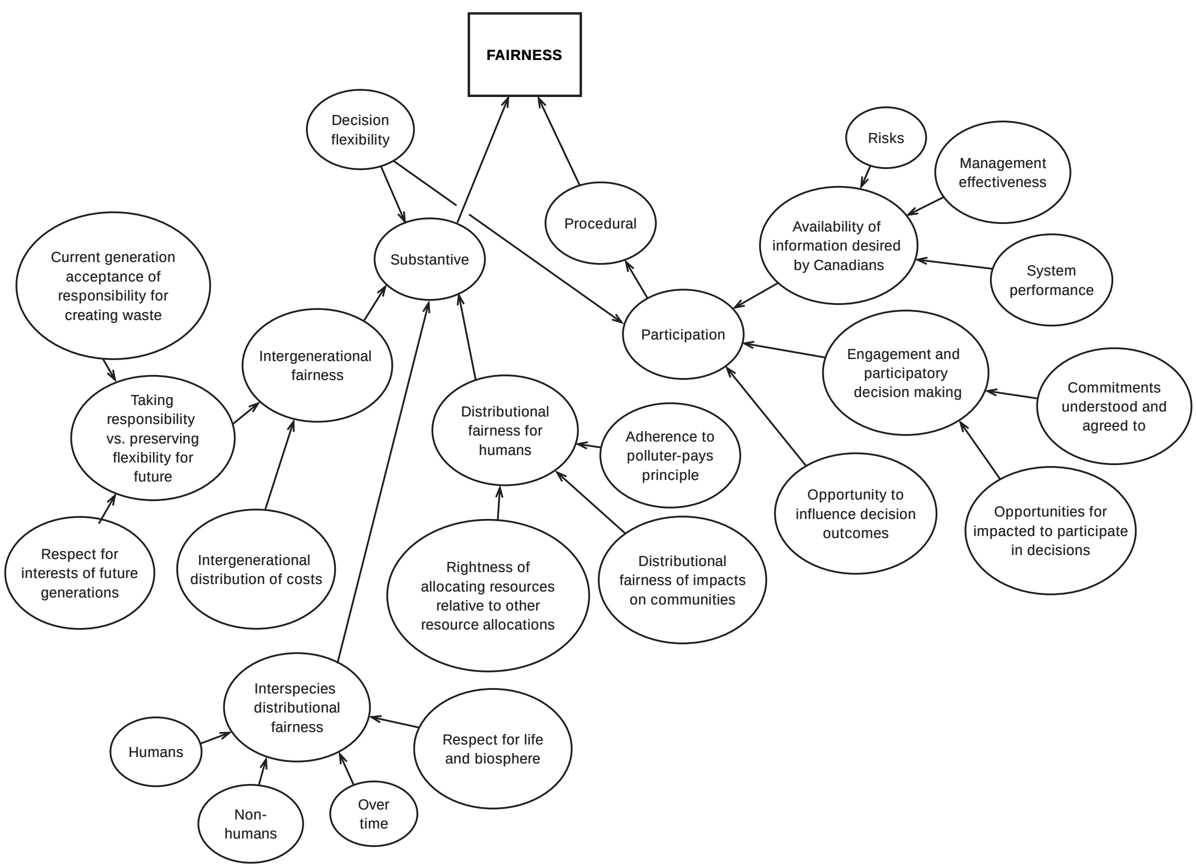


Table 3-1 Fairness

	BENEFITS	RISKS & UNCERTAINTY
All Approaches	All four management approaches have elements that support a strong claim to having distributed risks, costs, and benefits fairly across generations and within generations.	There are important but different uncertainties associated with each of the options in terms of intergenerational fairness.
Option 1: Deep Geological Disposal	Results in the eventual permanent placement of the used nuclear fuel, which reduces or may eliminate the necessity for long-term institutional and operational continuity and financial surety. As a consequence, after placement and closure, provision of long-term resources and funding are not required. It therefore places the responsibility on the current generation for ensuring that the long-term management facility is in place. It supports intergenerational fairness in limiting the burden on future generations to take further actions in managing the fuel. In the near term, provides the opportunity for public participation in the locating of the facility at a new central site. In the near term, it offers a significant economic boom to a host region and province. In the longer term, as a single centralized facility, it limits exposure to hazards and is designed to be passively safe which should limit overall risks and uncertainty.	In the longer term, provides little flexibility for future generations to influence the management of used nuclear fuel or to make fundamental changes without incurring considerable additional costs. Depending upon the economic region selected, could be in a region not having benefited from the production of nuclear energy. More communities will be affected since this option involves transportation of used nuclear fuel, however many if not all of these would likely have benefited from the power, at least indirectly. This risk is judged to be very small. In the short term, may be difficult to find an accepting host community or region. There is some uncertainty associated with how the system will perform over the long term. In the unlikely event of a breach of containment, it would be difficult for a future generation to detect the breach in a timely way and take corrective action. Although it offers a significant economic boom to a host region and province, this is expected to be followed by a rapid decline (bust) after Year 59.
Option 2: Storage at Nuclear Reactor Sites	In the short term, these communities have benefited from jobs and economic spin-offs associated with the nuclear plant and there is some element of fairness in having these same communities manage the waste from this activity while they receive benefits. Provides flexibility for future generations to influence the management of used nuclear fuel. It is easier to monitor human and environmental effects, to take corrective action, should it be required, and take advantage of new learning. Reactor site communities have experience in living and working in communities with nuclear facilities. In the near term, the infrastructure, including skilled workers, and well-developed security systems, is in place to support nuclear facilities. No transportation of used nuclear fuel would be required, as the used fuel would remain next to where it is generated and so other communities would not be affected. The science and technology required are well in-hand. Offers financial and economic benefits to six economic regions simultaneously with the greatest benefit occurring in south-central Ontario, where the majority of used nuclear fuel is currently located.	Places responsibility on future generations to take responsibility for managing the used fuel consumed by this generation through the requirement to actively manage the waste to ensure safety over tens of thousands of years. Social, technological and moral liabilities are placed on future generations who will have to address the current generation's used nuclear fuel, and ensure the ongoing financial surety to safely manage the operations in perpetuity. With multiple sites to be managed, the potential costs and risks passed on to future generations could be higher than with one centralized facility. Creates obligations for existing reactor site communities for the ongoing, long-term management of used nuclear fuel. This function was not envisioned when the reactor sites were chosen initially, nor was it understood by the communities and businesses that have chosen to locate in the vicinity of these facilities. In order for future generations to receive some advantage from the ability to access the waste and make incremental improvements should they wish, it will be necessary to ensure strong institutions and financial surety mechanisms continue to be in place over the very long term. This is an area of high uncertainty.

Table 3-1 (cont'd) Fairness

	BENEFITS	RISKS & UNCERTAINTY
Option 2: (cont'd) Storage at Nuclear Reactor Sites		Other parts of the province, if not country, have benefited from nuclear power and would not be sharing equally in the costs of managing the used fuel. Few if any contingency plans/options should current site(s) become compromised. Even though the benefits accruing to the community are cyclical (following the pattern of ongoing facility replacement, which is required with this approach), these cycles are far enough apart that the host region(s) cannot avoid a "boom and bust" type cycle and the attendant costs.
Option 3: Centralized Storage	Provides flexibility for future generations to influence the management of used nuclear fuel. It is easier to monitor human and environmental effects, to take corrective action, should it be required, and take advantage of new learning. The science and technology required are well in-hand. Provides the opportunity for public participation in the locating of the facility at a new central site. Provides for a facility that is purpose-built for long-term management. As a single centralized facility, it limits the exposure of populations to hazards. Provides flexibility for future generations to influence the management of used nuclear fuel. Provides more options where facility can be sited, since host geology is not a critical factor for this approach.	Places responsibility on future generations to take responsibility for managing the fuel consumed by this generation through the requirement to actively manage the waste to ensure safety over tens of thousands of years. Social, technological and moral liabilities are placed on future generations who will have to address the current generation's used nuclear fuel, and ensure the ongoing financial surety to safely manage the operations in perpetuity. In order for future generations to receive some advantage from the ability to access the waste and make incremental improvements should they wish, it will be necessary to ensure strong institutions and financial surety mechanisms continue to be in place over the very long term. This is an area of high uncertainty. Even though the benefits accruing to the community are cyclical (following the pattern of ongoing facility replacement, which is required with this approach), these cycles are far enough apart that the host region(s) cannot avoid a "boom and bust" type cycle and the attendant costs. Requires the identification and development of a site with potentially contentious community involvement. Transportation of the used nuclear fuel to the site would be required with its attendant risks and costs. This risk is judged to be small.

Table 3-1 (cont'd) Fairness

	BENEFITS	RISKS & UNCERTAINTY
Option 4: Adaptive Phased Management	Places the majority of responsibility on the current generation for ensuring that a long-term management facility is in place. Supports inter-generational fairness in limiting the burden on future generations to take further actions in managing the fuel. Responds to the sentiment of Canadian society, that the generations of citizens benefiting from nuclear power and creating the associated wastes have an obligation to provide a lasting means for managing that waste while at the same time preserving options for future generations to make decisions that they believe are in their own best interests. It calls for the construction of facilities early in the implementation process in order to ensure that this generation has provided for viable long term management facilities to reduce the burden on future generations. It calls for an extended period of flexibility in decision making in moving from current reactor site storage to eventual placement in a centralized deep repository and the potential sealing of this repository, in order to leave room for future generations to influence the final stages of implementation, particularly over the period in which it is reasonable to expect that societal institutions will remain strong. Provides for an extended validation and optimization program, to enhance ultimate performance of the facility. Through proactive contingency planning, it ensures there are safe and secure storage facilities available for management of the used fuel at each point in the process. Implementation is phased, allowing for time to learn and benefit from new science and emerging findings on technology and to continue to gauge the risk and uncertainty in light of new knowledge associated with moving through the phases. This includes leaving the decision to a future society regarding the best time for closing and sealing the deep repository. As a blend of a flexible centralized storage facility over the next 300 years, coincident with an extended period of proof of concept activities, and final placement of used nuclear fuel in a deep repository, is judged to provide the fairest distribution of benefits and risks within this generation and across generations. Involves the creation of a long-term facility that could be located away from existing communities. Provides the potential for the location of this facility to maximize fairness since the restrictions on the host geology for the deep repository are substantially less than for Option 1.	This approach attempts to balance the uncertainties and potential implications to fairness associated with Option 1 and with Option 3. It attempts to optimize flexibility in the near term, and ensure there is an option in place to contain and isolate the waste in the very long term, which does not rely upon human intervention. However, in so doing, it carries the risks of flexibility in the near term period, although these risks are expected to be less than in the storage approaches because the period of risk is timed to coincide to the period in which it is reasonable to believe we are in the best position to actively manage this risk. In the very long term, it also carries the risks associated with the repository system, although these risks are expected to be less as a result of the planned extended period of technology investigation, testing and confirmation and the adaptive staging embodied in this approach. Requires the identification and development of a site with potentially contentious community involvement. Transportation of the used nuclear fuel will involve more communities in the risk associated with the implementation of the approach. However it is expected that this risk will be small and that the approach to engagement in decision making at each step of the way of those who are affected embodied in this approach will ensure that fairness issues are identified and explicitly addressed before implementation proceeds. The fundamental importance of collaborative decision making at multiple points in the implementation, which is embodied in this approach, is also expected to ensure that fairness issues associated with siting, as these are understood by those most directly involved, will be identified and explicitly addressed before any site decision is made.

Summary Findings

Option 4 is judged to be the strongest of the options on the objective of fairness on both of its dimensions: substantial and procedural fairness.

Intergenerational fairness

Concerning intergenerational fairness, all four management approaches have elements which support a strong claim to having distributed risks, costs, and benefits fairly across generations although there are important but different uncertainties associated with each of the options. Option 1 provides for intergenerational fairness in placing the responsibility on the current generation – the generation benefiting from nuclear power – for ensuring that the long-term management facility is constructed and available to take the used fuel. Once the deep repository is closed, there are few if any requirements of future generations to ensure the continued isolation and containment of the waste. However, there is some uncertainty associated with how the system will perform over the very long term. In the unlikely event of a breach of containment, it would be difficult for a future generation to detect the breach in a timely way and take corrective action.

In contrast, Option 2 and Option 3, the storage options, provide for intergenerational fairness in offering a high degree of flexibility to future generations in terms of making their own decision about how best to manage the nuclear fuel. It would be easier to monitor human and environmental effects, to take corrective action should it be required, and take advantage of new learning. However, there is some uncertainty associated with whether societal capacity to actively manage the facility will endure for the thousands of years required with this approach. Should this capacity not exist in the future, then the storage options will have left an unmanageable and unfair burden on future generations.

Option 4 provides some balance between these two potential contributors to intergenerational fairness, and for this reason is judged to be the strongest of the approaches on this dimension:

- It calls for the construction of facilities early in the implementation process in order to ensure that this generation has provided for viable long-term management facilities;

- It calls for an extended period of flexibility in decision making in moving from current reactor site storage to eventual placement of used fuel in a centralized deep repository and in the potential sealing of this repository. This, in order to leave room for future generations to influence the final stages of implementation, particularly over the period in which it is reasonable to expect that societal institutions will remain strong;

- Through proactive contingency planning, it ensures there are safe and secure storage facilities available for management of the used fuel at each point in the process, including a facility which is designed to be passively safe should future societies be unable or unwilling to actively manage the used nuclear fuel; and

- Implementation is phased, allowing for time to learn and benefit from new science and emerging findings on technology. It also allows time to continue to gauge the risk and uncertainty in light of new knowledge associated with moving through the phases. In particular, a future society will determine the best time for closing and sealing the deep repository.

Interspecies distributional fairness

Concerning interspecies distributional fairness, all four management approaches are expected to be constructed and operated using best management practices. This is expected to minimize adverse effects on humans, non-human biota and the environment. In this respect, all four management approaches are judged to have a claim to be fair in terms of interspecies distributional fairness.

The key to ensuring interspecies distributional fairness is being able to prevent, effectively monitor, detect and mitigate adverse consequences in a timely manner. The question of whether one of these options is better than the others on this dimension, as with intergenerational fairness, requires judgment as to the magnitude of the uncertainties associated with: the capacity of future generations to actively manage a storage facility; and, the probability that a sealed deep repository will experience a major breach of containment.

It must be noted that Option 1 and Option 3, the approaches that involve the centralization of waste in a single facility, involve transportation and its associated risks and uncertainties. We expect that used nuclear fuel can be transported safety with little if any adverse effects to humans, non-human biota and the environment. We judge this to be a small incremental risk associated with these approaches. Option 4 attempts to provide a balance between the two major uncertainties mentioned above and for this reason is judged to be the strongest of the options on interspecies distributional fairness.

Distributional fairness

Implementation of any of the four management approaches is expected to bring significant employment and income (wealth) benefits to the local host economic region, the host province, and to Canada as a whole. The degree of benefit does vary considerably between the four management approaches, as outlined in the previous tables. Although we believe it will be important for any management approach selected to be implemented in a way which contributes to the wealth of the host community and region, and all reasonable efforts should be made in this regard, we believe the wealth benefits associated with each of the options should not drive the selection of the management approach.

Many of the same factors outlined above have a similar impact in consideration of distributional fairness. Although flexibility for future generations is preserved with the storage approaches, the distribution of costs is highly skewed to future generations. For both the storage options, social, technological, and moral liabilities are placed on many future generations who will have to deal with the current generation's used nuclear fuel. With the Deep Geologic Disposal approach, the distribution of costs is skewed toward current generations, however future generations are bequeathed a lesser ability to easily actively manage their risk through monitoring the used fuel and taking corrective action should it be required.

Transportation is a consideration in terms of the geographic distribution of benefits and risks. The options which require transportation of used nuclear fuel to a centralized site, Option 1 and Option 3, communities along the transportation route(s) would be expected to incur some added risks but few, if any, benefits as transportation services and infrastructure may originate from outside these regions. However, these risks are limited in time duration and are expected to be very low. As such, this is not judged to be a determining factor by the NWMO.

Option 4, as a blend of a flexible centralized storage facility over the next 300 years, coincident with an extended period of proof of concept activities, and final placement of used nuclear fuel in a deep repository, is judged to provide the fairest distribution of benefits and risks within this generation and across generations.

Participation

Procedural fairness is influenced by the degree to which the approach would allow for the participation of concerned citizens in key decisions about how the approach would be implemented. This includes consideration of the opportunities for decision-making provided by the approach and the availability of information that would be helpful for driving those decisions.

Storage at reactor sites was viewed as least fair for several reasons. Perhaps most importantly, this storage approach would obligate existing reactor sites with on-going, long-term management of used nuclear fuel. This function was not envisioned when the reactor sites were initially chosen, nor was it understood by the communities and businesses that have chosen to locate in the vicinity of these facilities.

By contrast, the centralized storage and deep geological disposal approaches involve facilities that could be located away from existing communities, thus lessening the unfairness of involuntarily subjecting many people to additional risks. The opportunity for public participation in the locating of a centralized storage or deep disposal facility was seen to be a positive attribute with regard to fairness, assuming that the siting process would be a voluntary one. Option 4 shares the same benefits as Option 1 and Option 3, and is therefore judged to be among the strongest on this fairness dimension.

Public Health and Safety Analysis

Our objective:
To ensure public health and safety.
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 used nuclear fuel transportation or other operations associated with the management of used nuclear fuel.

In assessing the options against public health and safety, we considered many factors, depicted graphically in the influence diagram below. We believe that any management system employed will result in direct or indirect risks to the health and safety of affected individuals or communities that are fully acceptable according to current safety standards. The possibilities of unplanned events that could present unexpected risks or stresses must be considered, and appropriate contingency action provided. There should not be foreseeable outcomes of the approach that lead to greater risks to the public from the used nuclear fuel facility at any time in the future than is acceptable today.

The physical, chemical and radiological characteristics of used nuclear fuel, and their hazards, are well understood. Those hazards are managed to prevent unreasonable risk, and licensing requirements and compliance verification by the Canadian Nuclear Safety Commission ensure that the effectiveness of any management approach will be monitored.

In the following diagram, we depict the scope of influences that we considered. The public health and safety aspects of each approach were assessed under both the short (1 – 175 year) and long (greater than 175-year) time-frames. Risks were estimated under normal, expected operating conditions and under “off-normal” scenarios in which members of the public might be inadvertently exposed to hazards associated with the various approaches.

Under normal operating conditions, risks associated with the following operations were considered: packing for shipment, transfer from old to new canisters, vehicle accidents, canister transport to dry storage and exposures during monitoring.

Comparative Assessment

Table 3-2 presents our assessment of the relative benefits and risks and uncertainty for each of the four options studied.

Figure 3-3 Public Health and Safety Influence Diagram

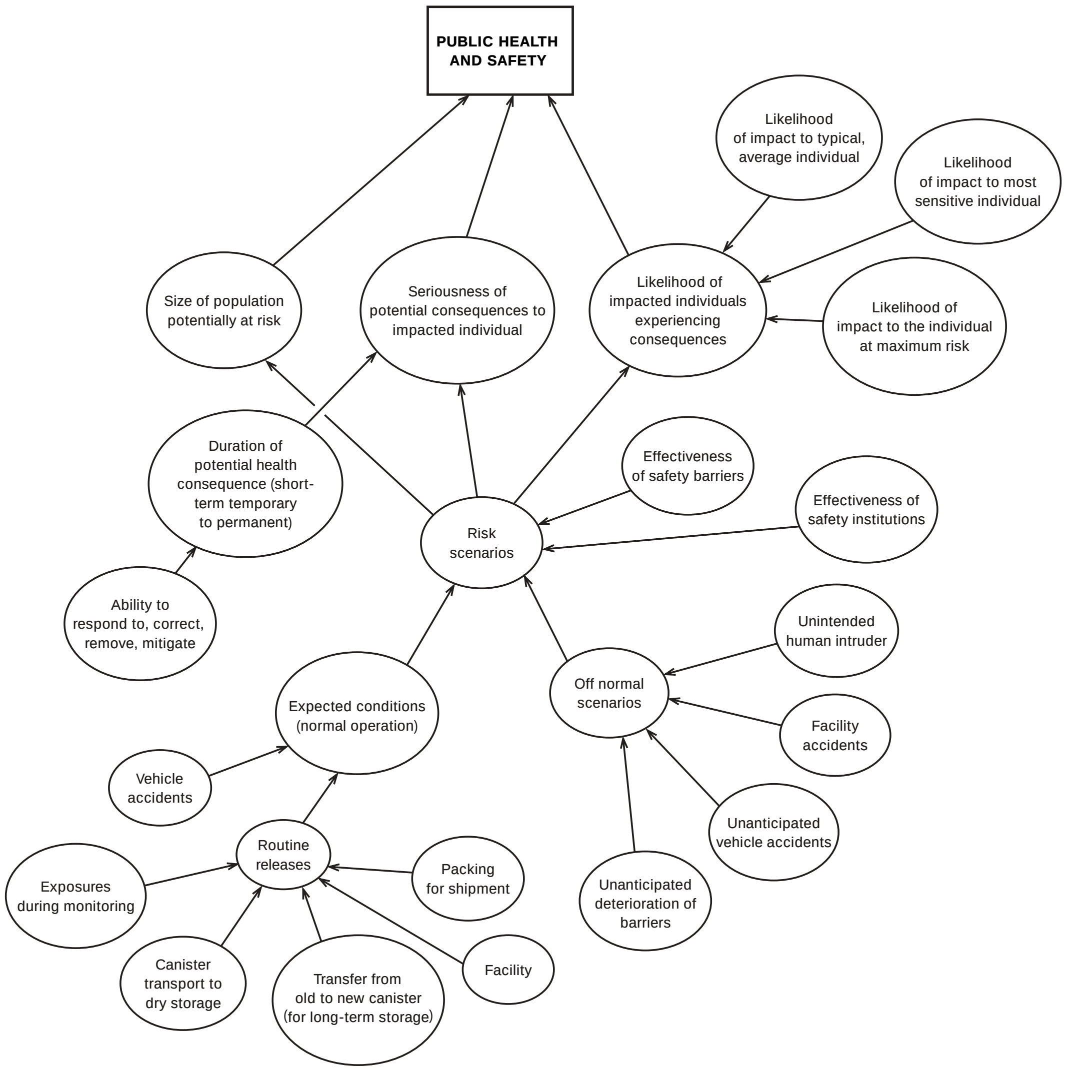


Table 3-2 Public Health & Safety

	BENEFITS	RISKS & UNCERTAINTY
Option 1: Deep Geological Disposal	Radiological and non-radiological exposure to the public is expected to be well within Canadian regulatory standards and norms with the performance and operation of the facility as designed. The public health and safety benefits, in comparison with the other options, are judged to be most pronounced in the very long term. The intrinsic geological features of the site, in combination with engineered features such as long-lived waste packages and material buffers are designed to isolate the used nuclear fuel from the accessible environment for the very long time periods that they remain hazardous. Not reliant on ongoing institutional control of the facility, it avoids risks that might otherwise be posed in the event of long-term societal instability. Deep underground placement reduces safety concerns both before and after closure because the materials would be difficult to access. Probability of human intrusion into the closed repository is very low. Offers protection from unacceptable risks through unauthorized or inadvertent intrusion into facility in the long term. Being located deep underground, the radioactive materials would be very difficult to access. May be sited away from population centres and so fewer people would be potentially at risk.	There is some uncertainty regarding the performance of the system over the very long term because advance “proof” that such a system works is not scientifically possible. Detailed scientific studies, models and codes, and natural analogues therefore, form the foundation of the assurances of performance. Monitoring of system performance becomes more difficult once the used nuclear fuel is placed deep underground and as the site is backfilled and closed. In the unlikely event of a breach of containment, the breach would be relatively more difficult to detect and address than in the storage options. Retrieval of the used fuel for corrective action is difficult and costly, and would involve similar risks to the public as waste placement. Transportation of the used nuclear fuel will be required and there is some risk to people along the transportation route because of conventional transport accidents. Robust containers are designed to ensure radiation containment in the face of a broad range of accident scenarios, covering both common and extreme events. Overall, radiation exposures for normal and off-normal transportation activities are considered very small. Risk of transport accidents depends on transportation distances and routes. Economic regions farther away from the source of used fuel will potentially expose more members of the public to risk. Flexibility to address changing environmental conditions is low, however changing conditions are not expected to affect the performance of the system. Reversibility of decisions is difficult once facility is closed. Indications are there is a lack of confidence by substantial proportion of Canadians that enough is known to proceed with this option at this time, and that the waste can be transported safely. During normal and off-normal conditions in the near term, all potential exposures are expected during or just after placement of the fuel in the facility. Movement of radioactivity through the groundwater pathway is possible for hundreds of thousands of years into the future. However, predicted impact is well below applicable standards because of isolation provided by the host geological formation. Probability of Maximum Impact to Receptor: The probability of the bounding off-normal scenarios during the near-term for all approaches is very low (less than 10^{-4}/year). The probability of human intrusion into the Deep Geological Disposal in the long-term is very low (less than 10^{-7}/year) .

Table 3-2 (cont'd) Public Health & Safety

	BENEFITS	RISKS & UNCERTAINTY
Option 2: Storage at Nuclear Reactor Sites	Radiological and non-radiological exposure to the public is expected to be well within Canadian regulatory standards and norms with the performance and operation of the facility as designed. Movement of radioactivity is prevented through active management and institutional controls. The public health and safety benefits, in comparison with the other options, are judged to be most pronounced in the shorter term. In the short term, storage facilities are easy to monitor, making it easy to identify problems and take corrective action. Current capacity for effective management of existing facilities exists and has been demonstrated. The science and technology required are well in-hand. Existing processes have a record of ensuring protection of public health and safety and operating well within regulatory benchmarks in the near term. There is a reasonable expectation of the continuation of this performance over the near term. Each of these sites already houses nuclear installations, so there is nuclear expertise on site and in the existing communities. Ability to monitor and demonstrate the ongoing performance is high. Flexibility to adapt to changing conditions or new information is high. With the option of shallow below-ground storage, some safety concerns are diminished. No transportation of used nuclear fuel is required, as the used fuel would remain where it is generated; therefore there are no off-site transportation related risks.	In the long term, lacks the natural barriers afforded by placing the used nuclear fuel deep underground, and for this reason the safety of the facilities depends primarily on active management and maintaining institutional controls that prevent or restrict access. This may be increasingly difficult over the long term, because, for example, of the possibility that social instabilities might occur at some future time period, future societies may not be as safety conscious as we are today, safety operations may become lax over time, and/or the possibility of extreme natural or human induced events in the long term. Over the long term, the potential for events that might trigger exposure will increase. For example, there are risks that extreme natural events such as very high winds, rise in sea level, global warming or cooling, and earthquakes could damage the facilities, particularly given the location of some facilities in higher siesmic zones and adjacent to large bodies of water. If the integrity of institutions is compromised as it may be in the future, the value of monitoring and flexibility is lost, and in fact becomes a liability. Storage at seven sites, rather than one central site, introduces possible risk to a greater number of people. As well, these reactor sites were selected for their suitability for reactor operation, not for very long term safe storage of used nuclear fuel. The fact that several of these sites are located near larger population centres further increases the potential risk to the public. The used nuclear fuel will remain hazardous well beyond the decommissioning and ultimate abandonment of the nuclear reactor site. Although corrective action expected to be easier, alternative options (contingency plans) in the event of unplanned circumstances are very limited. Repeated repackaging cycles cause an associated radiation exposure well into the future (greater than 10,000 years). If institutional control is not maintained, human intrusion into the facility is likely, with the resulting radiation exposures and unacceptable risk to the public.

Table 3-2 (cont'd) Public Health & Safety

	BENEFITS	RISKS & UNCERTAINTY
Option 3: Centralized Storage	Radiological and non-radiological exposure to the public is expected to be well within Canadian regulatory standards and norms with the performance and operation of the facility as designed. Movement of radioactivity is prevented through active management and institutional controls. The public health and safety benefits, in comparison with the other options, are judged to be most pronounced in the shorter term. In the short term, storage facilities are easy to monitor, making it easy to identify problems and take corrective action. Current capacity for effective management of similar types of facilities exists and has been demonstrated. The science and technology required are well in-hand. Existing processes have a record of ensuring protection of public health and safety and operating well within regulatory benchmarks in the near term. There is a reasonable expectation of the continuation of this performance over the near term. Ability to monitor the performance is high. Flexibility to adapt to changing conditions or new information is high. With the option of shallow below-ground storage, some safety concerns are diminished. Would allow for site selection solely on the basis of used nuclear fuel management and its public health and safety impacts. That is, the facility could be sited and designed to protect public health and safety. Siting choices extend to both economic regions on the Canadian Shield and on areas of sedimentary rock, offering greater opportunities to limit transportation distances.	In the long term, lacks the natural barriers afforded by placing the used nuclear fuel deep underground, and for this reason the safety of the facilities depends primarily on active management and maintaining institutional controls that prevent or restrict access. This may be increasingly difficult over the long term, because, for example, of the possibility that social instabilities might occur at some future time period, future societies may not be as safety conscious as we are today, safety operations may become lax over time, and/or the possibility of extreme natural or human induced events in the long term. Over the long term, the potential for events that might trigger exposure will increase. For example, there are risks that extreme natural events such as very high winds, rise in sea level, global warming or cooling, and earthquakes could damage the facility. These risks will be mitigated in part by careful selection of the centralized site, and by the fact that there is only one facility. If the integrity of institutions is compromised as it may be in the future, the value of monitoring and of flexibility is lost, and in fact becomes a liability. Transportation of the used nuclear fuel will be required and there is some risk to people along the transportation route because of conventional transport accidents. Robust containers are designed to ensure radiation containment in the face of a broad range of accident scenarios, covering both common and extreme events. Overall, radiation exposures for normal and off-normal transportation activities are considered very small. Risk of accidents depends on transportation distances and routes. Economic regions farther away from the source of used fuel will potentially expose more members of the public to risk. Repeated repackaging cycles cause an associated radiation exposure well into the future (greater than 10,000 years). If institutional control is not maintained, human intrusion into the facility is likely, with the resulting radiation exposures and unacceptable risk to the public.

Table 3-2 (cont'd) **Public Health & Safety**

	BENEFITS	RISKS & UNCERTAINTY
Option 4: Adaptive Phased Management	Radiological and non-radiological exposure to the public is expected to be well within Canadian regulatory standards and norms if facility built to specification and managed as designed. It allows time to establish confidence in both transportation and the efficacy of the deep repository concept, before proceeding with them. Allows for an extended validation and optimization program, so that full advantage can be taken of early repository system operation to justify confidence in performance or permit necessary additional measures to be taken during the period when institutional integrity is more certain. It allows a period of time of high flexibility in which new learning might be easily incorporated. It allows confidence to be established through a stepwise process that can be adapted to mirror public confidence building. In the long term, when institutional integrity is most uncertain, it offers important public health and safety advantages of multiple engineered and geological barriers for used nuclear fuel isolation. Being located deep underground, the radioactive materials would be contained and isolated and difficult to access. In the deep repository, the used fuel is protected by both robust natural barriers provided by the geological formation (crystalline or sedimentary rock), as well as the engineered barriers in terms of container design, buffer materials, etc. The facility can be sited and designed to protect public health and safety by minimizing the likelihood that material released would come into contact with the public. Siting choices extend to economic regions on the Canadian Shield and suitable areas of sedimentary rock, offering greater opportunities to limit transportation distances.	Between Year 154 and 325 (i.e., prior to closure), if there is a loss of institutional control, this approach does not prevent an unacceptable radiation exposure risk to public health and safety caused by human intrusion. Transportation of the used nuclear fuel will be required and there is some risk to people along the transportation route because of conventional road accidents. Robust containers are designed to ensure radiation containment in the face of a broad range of accident scenarios, covering both common and extreme events. Overall, radiation exposures for normal and off-normal transportation activities are considered very small. Risk of conventional road accidents increases with transportation distances. Economic regions farther away from the source of used fuel will potentially expose more members of the public to risk.

Summary Findings

For all four options, public health and safety is expected to be assured in the near term provided that the facilities are built and operated as designed. In all cases, public health and safety would be protected through the use of multiple barriers to contain and isolate the used nuclear fuel from the environment. These natural barriers will be enhanced by institutions and oversight focused on ensuring that standards are met for both radiological and non-radiological exposures. Over the near term, accessibility and flexibility, in combination with strong institutional control, is judged to be the approach which best protects public health and safety. It allows for continuous learning and incremental improvements to be made.

Over the long term, a passive system that can effectively contain and isolate the material without requiring institutional control is judged to be a better approach to safety than one that continues to rely upon institutions.

Over the long term, Options 1 and 4, which attempt to achieve passive safety through a combination of engineered and natural geological barriers are preferable to storage approaches which rely to a large extent on institutional control to maintain safety. The combination of robust engineered barriers, together with the geological barriers associated with placement deep underground, is more likely to effectively contain and isolate the used fuel for the thousands of years over which the material remains hazardous.

Storage options such as those envisaged under Options 2 and 3 have a strong track record of effective management and ensuring public health and safety to date. There is every reason to expect continuation of positive operating performance over the near term. The significant downside risk associated with these storage options relates to their reliance on ongoing institutional controls and societal oversight, which cannot be relied upon in perpetuity. Without the benefit of the multiple barriers, including geologic barriers, these options require ongoing active management and monitoring to ensure public health and safety.

When both the near term and the long term are considered, Option 4 is judged to offer the greatest benefits in terms of public health and safety. In the near term, the staged management of this approach allows for continuous learning that enables us to address many areas of uncertainty and establish further confidence in the deep repository concept before proceeding. Option 4 allows for a high degree of flexibility in implementation, offering time to learn and observe emerging science and to incorporate new developments that may emerge over the next few decades. Contingencies are available at each point in the process to ensure effective containment and isolation of the used nuclear fuel. The approach envisages the possible role for interim centralized storage below ground, as an important step along the implementation path. And it allows for future generations to make the determination when the deep repository is most appropriately closed and sealed, as the last step in providing permanent safety and security. Over the long term, the combination of natural geological and engineered barriers would be designed to ensure that public health and safety are protected even in the absence of institutional controls.

In order to best protect the health and safety of individuals and the public at large, we understand that an optimal balance needs to be found between flexibility in the near term, which allows for new learning, and the implementation of an approach which isolates and contains the used fuel in a way which does not require active care by people over the very long term. In suggesting Option 4, we are attempting to suggest such a balance.

Worker Health and Safety Analysis

Our objective:

To ensure worker health and safety.

Construction, mining and other tasks associated with managing used nuclear fuel can be hazardous. The selected approach should not create undue or large risks to the workers who will be employed to implement it.

In assessing options for impacts on worker health and safety, we considered a number of factors. The management system and the technologies used, the design, 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, workers involved with the used nuclear fuel facility should not be subject to risks or harmful exposures, chronic or accidental, greater than those acceptable to Canadian or international authorities at the time of construction. Workers engaged in future monitoring or maintenance activities should not be subject to risks greater than those acceptable today.

The complete list of influences we considered is identified in the following diagram.

Risks were separately estimated for two time periods. They were estimated based on normal, expected operating conditions and under "off-normal" scenarios in which workers might be inadvertently exposed to hazards associated with the various approaches. Under normal operating conditions, worker risks associated with the following operations were considered: construction, transportation, fuel handling, and monitoring. The main "off-normal" risk scenarios considered included an extreme construction accident, accidental radiological exposures and extreme fuel handling accidents.

Comparative Assessment

Table 3-3 presents our assessment of the relative benefits and risks and uncertainty for each of the four options studied.

Figure 3-4 **Worker Health and Safety Influence Diagram**

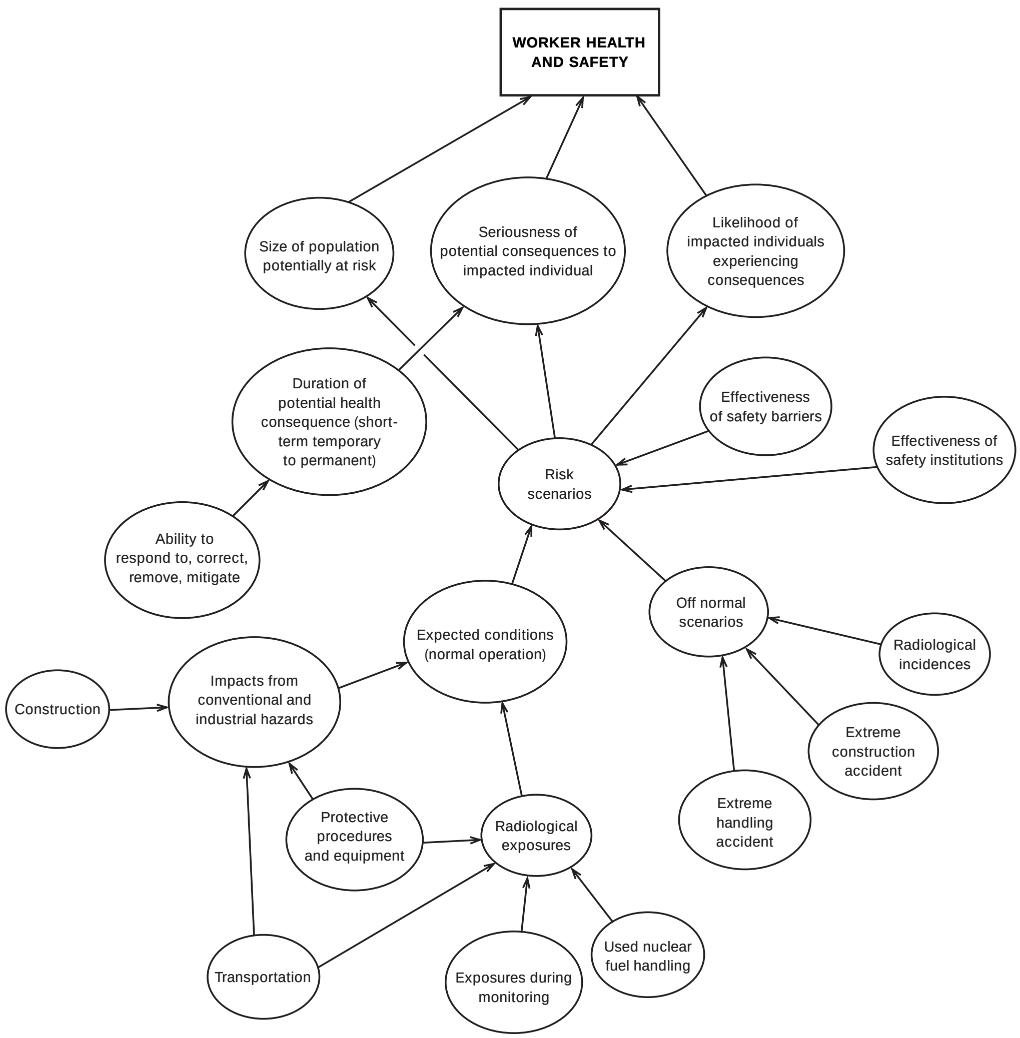


Table 3-3 Worker Health & Safety

	BENEFITS	RISKS & UNCERTAINTY
Option 1: Deep Geological Disposal	Radiological and non-radiological risks to workers during operations and transportation expected to be well within Canadian regulatory standards and norms. Minimal radiation exposure of workers over the long term. Avoids radiation exposure to workers from ongoing perpetual repackaging and handling of the fuel. Once the facility is closed, no additional worker activities required.	In the short term, would require the relatively higher risk tasks of mining and earth moving. The size of the workforce required to support implementation of this option, and the number of workers potentially at risk, is about three times higher than for Options 2 and 3 in the near term. However, much of the work would be mechanized and a relatively small number of workers would be directly involved in hazardous operations. In the short term, the risks to workers arise mainly from construction and transportation requirements, and are non-radiological in nature. Even though radiological exposures may well occur, based on the adoption of safe operating practices and robust oversight, they are unlikely to cause serious health consequences. Would involve transportation of used fuel, with the potential risks of traffic accidents and other dangers to drivers. The level of risk to workers through traffic accidents will be affected by the specific routes taken and transportation distance and therefore the choice of economic region selected for the deep geological disposal facility.
Option 2: Storage at Nuclear Reactor Sites	Radiological and non-radiological risks to workers during operations expected to be well within Canadian regulatory standards. Does not require off site transportation, thus avoiding the risks to workers associated with transport-related accidents. Involves minimal construction risks.	Produces worker risks during the refurbishment of existing facilities and construction of new facilities repeatedly as the containers degrade and the fuel must be repackaged. The risks are greater than with Option 1 because significantly more handling and packaging would be required. Some risk of injury is associated with the requirement for ongoing repackaging and handling of used fuel in perpetuity. Construction risks extend into the long term, due to the fact that the facility will need to be rebuilt every 300 years. Institutions must continue to function well to ensure that the safe practices that protect workers (and others) do not decline. As long as institutions remain effective, unacceptable risks to workers due to radiation exposure are unlikely. Has all of the on-site worker risks associated with the centralized storage approach plus would require continuing operations involving more workers at multiple sites with differing conditions.

Table 3-3 (cont'd) Worker Health & Safety

	BENEFITS	RISKS & UNCERTAINTY
Option 3: Centralized Storage	Radiological and non-radiological risk to workers during operations and transportation expected to be well within Canadian regulatory standards and norms.	Produces worker risks during the construction of the facility and repeatedly as the containers degrade and the fuel must be repackaged. The risks are greater than with Option 1 because significantly more handling and packaging is required. Some risk of injury is associated with the requirement for ongoing repackaging and handling of used fuel in perpetuity. Construction risks extend into the long term, due to the fact that the facility will need to be rebuilt every 300 years. Institutions must continue to function well to ensure that the safe practices that protect workers (and others) do not decline. As long as institutions remain effective, unacceptable risks to workers due to radiation exposure are unlikely. Would involve transportation of used fuel, with the potential risks of traffic accidents and other dangers to drivers. The level of risk to workers through traffic accidents will be affected by the specific routes taken and transportation distance and therefore the choice of economic region selected for the centralized storage facility.
Option 4: Adaptive Phased Management	Radiological and non-radiological risk to workers during operations and transportation is expected to be well within Canadian regulatory standards. With closure of facility by year 325, reduces exposure of workers over the long term. Reduces potential exposure to workers through ongoing perpetual repackaging and handling. Phased implementation, with possibility of interim underground storage in rock caverns would involve slightly more handling of the fuel than in Option 1, but less than with Options 2 and 3.	The size of the workforce required to support implementation of this option is about three times higher than for Options 2 and 3, in the near term. Would involve transportation of used fuel, with the potential risks of traffic accidents and other dangers to drivers. The level of risk to workers though traffic accidents will be affected by the specific routes taken and transportation distance and therefore the choice of economic region selected for the central facility. Siting choices extend to both economic regions on the Canadian Shield and suitable areas with sedimentary rock, offering opportunities to limit transportation distances and associated worker risk as compared to Option 1. Low levels of worker risk would continue through to year 325 during longer period of institutional control and monitoring as compared to Option 1.

Summary Findings

In all four options, radiological and non-radiological risks to workers during operations and transportation are expected to be well within Canadian regulatory standards and norms.

Options 1 and 4 offer the lowest risk to workers because these approaches limit risks to workers to finite periods of time during which the centralized facilities are built, the sites investigated, and used fuel is moved and placed into the facilities. Worker risk would be slightly higher under Option 4, which involves an expanded implementation timeline for additional monitoring and phased decision-making compared with Option 1.

In contrast, Options 2 and 3 require ongoing risks to workers because storage operations would continue in perpetuity, with ongoing requirements for repackaging and handling of used fuel. It is expected that up to 100 repackaging cycles would be required over a 10,000-year period.

The consolidation of the used fuel to a single site associated with Option 3 incrementally reduces the worker risks associated with Option 2, which would require ongoing operation and fuel handling at seven different locations. This is because with consolidation, fewer workers are involved with Option 3 and process optimization and oversight to ensure worker safety would be easier to achieve at a single site rather than at multiple sites.

Community Well-Being Analysis

Our objective:
To ensure community well-being.
Implications for the well-being of all communities with a shared interest (including host community, communities in the surrounding region and on the transportation corridor, and those outside of the vicinity who feel affected) should be considered in the selection and implementation of the management system and related infrastructure. A broad range of implications must be considered, including those relating to economic activity, environmental disruption and social fabric and culture.

The assessments with respect to community well-being considered both the likely economic impacts of the approach, and the potential effects on social and cultural qualities of affected communities. On the economic side, consideration was given to potential effects on property values, jobs and businesses. Potential social and cultural impacts include raising fears and concerns of citizens and the risk of community polarization (e.g., contrasting beliefs between those who support and those who oppose locating a facility near their community). Some residents may see living near a radioactive waste management facility as placing a stigma on their community. The list of influences considered is depicted in the diagram below.

Comparative Assessment

Table 3-4 presents our assessment of the relative benefits and risks and uncertainty for each of the four options studied.

Figure 3-5 Community Well-Being Influence Diagram

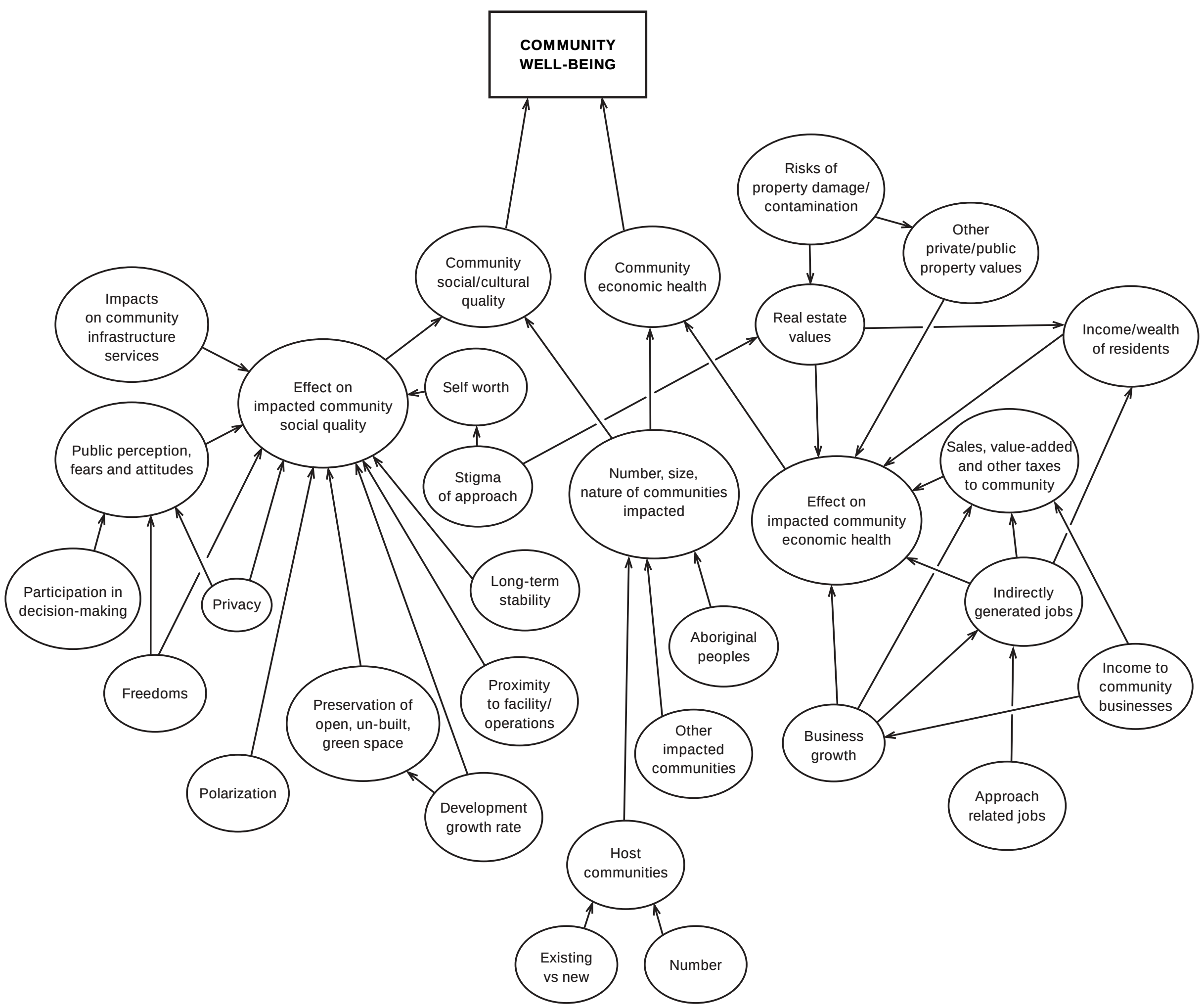


Table 3-4 Community Well-Being

	BENEFITS	RISKS & UNCERTAINTY
All approaches	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. Provides substantial economic benefits in terms of the creation of thousands of jobs, billions of dollars in new income and new tax revenue to all three levels of government. Well executed implementation will enable these benefits to be aligned with the realization of social, cultural and economic aspirations and support the long-term stability of the affected communities. Economic impacts would extend to enhancements to community infrastructure associated with supporting the facility, such as construction of improved roads and generation of higher–paying jobs.	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 involve thousands of workers and billions of dollars in expenditures with likely temporary effects on: housing and land values; demand for social and physical infrastructure services from influx of short term and temporary workers; and local and regional government tax revenues. The analysis of eleven illustrative economic regions (described in Section 9.2) 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. The more rural and remote regions, including some Aboriginal communities, have lower adaptive capacity. Should a facility be sited in such a region, adequate support would need to be given to these communities to ensure they are able to effectively participate in decision-making and ensure a full slate of benefits accrues to them. As well, Aboriginal communities and those who have chosen to live in less populated areas may be concerned about the development commercializing their way of life, and cultural disruption in general.
Option 1: Deep Geological Disposal	Is expected to be implementable with no adverse consequences to the community, assuming a decision-making process that involves affected communities, and appropriate mitigation measures are taken. Economic benefits are provided in the near-term (within the first 175 years). Significant expenditures on transportation required to support this option generate thousands of jobs and income that extend beyond the host region. Facility can be located at a new centralized site, away from existing reactor communities, thereby allowing the invitation of a willing host community. With no significant operations required in the long term, the facility would not lead to the same repeat cycles of boom and bust associated with Options 2 and 3. Results in the eventual permanent placement of the used nuclear fuel, which reduces the necessity for long-term institutional and operational continuity and financial surety.	Along with the economic benefits, there are a variety of uncertainties and social and economic costs attendant with projects of this magnitude. Creating a new facility in a new location may create more adverse impacts on communities than leaving the waste where it is. Requires transportation away from existing reactors and would likely raise concerns of communities along the transportation routes, particularly if the safety of transportation had not yet been established. Communities on transportation routes would need to have concerns addressed. Over the long term, the limited opportunity to demonstrate system performance (for instance by monitoring and access) may be a source of lingering concern among some in the community.

Table 3-4 (cont'd) Community Well-Being

	BENEFITS	RISKS & UNCERTAINTY
Option 1: (cont'd) Deep Geological Disposal	In the near term (less than 175 years), both Option 1 and Option 4 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 of eight compared to Centralized Storage (above or below ground). Option 1 and Option 4 are roughly equivalent in economic value in each illustrative economic region.	
Option 2: Storage at Nuclear Reactor Sites	Is expected to be implementable with no adverse consequences to the community, assuming a decision-making process that involved affected communities, and appropriate mitigation measures are taken. Economic benefits to the community are spread out over thousands of years. In the long-term (after year 175), only Option 2 and Option 3 generate any significant economic benefits from ongoing maintenance and cyclical facility rebuilding. Consequently economic, employment and income generating benefits continue for thousands of years. This option is the only approach that simultaneously develops facilities at all seven current reactor sites. Benefits are more widely distributed across 6 regions/7 sites, with the regions managing the largest volumes of used fuel capturing the greatest share of benefits. The most urbanized region tends to gain the most economic benefit in absolute terms. Further, the ability to monitor the performance and the flexibility to adapt to changing conditions is facilitated.	Boom and bust cycles associated with Option 2 continue through the ongoing operation of the facilities, repeated cyclically with the repackaging and facility rebuilding required every 100 years and 300 years respectively. Need for continuing administrative controls and operations, including the necessary funding, for the thousands of years the used nuclear fuel remains hazardous. These reactor sites were selected for their suitability for reactor operation, not for very long-term storage of used nuclear fuel and therefore may not be ideal for this purpose. The used nuclear fuel will remain hazardous and need to be secured well beyond the almost certain shutdown and ultimate abandonment of the nuclear reactor sites. Multiple sites would need to be secured, some located next to important bodies of water. Changing the role of the reactor storage sites from temporary to long term would involve significant facility upgrades – there is potential to polarize the more immediate community because some people may feel betrayed by the change of status of the facility from interim to long-term waste management. As well, the proximity of a facility that is acknowledged to involve risks may be a target for citizen legal action.

Table 3-4 (cont'd) Community Well-Being

	BENEFITS	RISKS & UNCERTAINTY
Option 3: Centralized Storage	Is expected to be implementable with no adverse consequences to the community, assuming a decision-making process that involved affected communities, and appropriate mitigation measures are taken. Economic benefits to the community are spread out over thousands of years. The extent of benefits captured locally depends upon the nature of the economic region hosting the facility. As with storage at nuclear reactor sites, the required science and technology are well in hand. Further, the ability to monitor the performance and the flexibility to adapt to changing conditions is facilitated. If done well, siting can be achieved with community participation.	Boom and bust cycles associated with Option 3 continue through the ongoing operation of the facilities, repeated cyclically with the repackaging and facility rebuilding required every 100 years and 300 years respectively. Centralized storage shares with the at-reactor storage option the key disadvantage of requiring effective and continuing administrative controls and operations, including the required funding, for thousands of years. Creating a new facility in a new location may create more adverse impacts on communities than leaving the waste where it is. Requires transportation away from existing reactors and would likely raise concerns of communities along the transportation routes, particularly if the safety of transportation had not yet been established. Communities on transportation routes would need to have concerns addressed.
Option 4: Adaptive Phased Management	Is expected to be implementable with no adverse consequences to the community, assuming a decision-making process that involved affected communities, and appropriate mitigation measures are taken. Phased implementation allows for a more gradual implementation period, and more opportunity for community adjustment than is possible with Option 1. In selecting a location from a greater range of potentially suitable economic regions for implementation than is possible with Option 1, this approach offers greater opportunity to limit the scope of adverse social, human, physical and financial impacts on the host community. Is most amenable to responding to changes that may occur over the implementation period, and thereby maintaining public confidence. Over the decades of program development and implementation, the selected approach will encounter changes in society, technology, economics, and the environment. These changes will be further influenced by the evolving political and institutional landscape and more. This approach is staged to include periodic sequential decision points that give greater opportunity for stakeholders, and specifically the affected communities, to participate in the design, and evaluation of the program status for progressive decision-making. Explicitly recognizes, and plans for, the breadth of communities which will be impacted over the course of eventual implementation of a deep repository. In the near term (less than 175 years), both Option 1 and Option 4 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 of eight compared to Centralized Storage (above or below ground). Option 1 and Option 4 are roughly equivalent in economic value to each illustrative economic region. However, the benefits of Option 4 are stretched out over a longer time period (i.e. 30 years longer than Option 1).	Along with the economic benefits, there are a variety of uncertainties and social and economic costs attendant with projects of this magnitude. Creating a new facility in a new location may necessarily create more adverse impacts on communities than leaving the waste where it is. These adverse impacts are expected to be substantially less than for Option 1 due to the greater flexibility in siting the facility which Option 4 provides for. Requires transportation away from existing reactors and would likely raise concerns of communities along the transportation routes, particularly if the safety of transportation had not yet been established. Communities on transportation routes would need to have concerns addressed. Over the very long term, the limited opportunity to demonstrate system performance (for instance by monitoring and access) may be a source of lingering concern among some in the community. However, this is expected to be substantially less than for Option 1 because of the extended period of confirmation of performance which this option involves. Need for continuing administrative controls and operations, including the necessary funding, for a longer period than for Option 1, although it is judged reasonable to believe that institutions will continue to remain strong during this period.

Summary Findings

All four approaches are expected to provide significant economic benefits to all Canadians, host province, region and community.

For any approach, implementation plans must be designed collaboratively with communities to facilitate the community's social, cultural and economic aspirations and avoid or minimize adverse impacts.

Centralized approaches, Options 1, 3 and 4, allow the invitation of a willing host community as part of the site selection process, and the opportunity to work closely with the selected community to design implementation in a way that is supportive and responsive to the priorities of the community.

Option 4, in presenting a staged and adaptive approach, allows the implementation path to be responsive to the expectations of Canadian society and continued influence of future generations on the subsequent decisions to be taken concerning design and evaluation of program progress. Option 4 recognizes that a range of communities will be impacted, and seeks to build confidence through a stepwise implementation path.

Security Analysis

Our objective:
To ensure security of facilities, materials and infrastructure.
The selected management approach needs to maintain the security of the nuclear materials and associated facilities. For example, over a very long time-frame, the hazardous materials involved ought to be secure from the threat of theft, despite possibilities of terrorism or war.

An approach must ensure the security of both nuclear materials and the facilities that manage them. Although a loss of nuclear material would likely pose health and safety risks to Canadians, maintaining security would be an objective even if the lost fuel was sure to be transported out of Canada. Canadians would not want the people in other countries to be at risk from radioactive materials stolen from Canada. Thus, security is a fundamental objective that goes beyond protecting the health and safety of Canadians.

To assess security, the vulnerability of each approach to various risk scenarios was considered. The risk scenarios included terrorism and potential "insider" threats focused on theft, diversion, sabotage, and "seize and hold" strategies. The adequacy of contingency plans and the robustness of the approach under scenarios involving societal breakdown and civil disobedience were also considered. The influences considered are outlined in the diagram below.

Comparative Assessment

Table 3-5 presents our assessment of the relative benefits and risks and uncertainty for each of the four options studied.

Figure 3-6 Security Influence Diagram

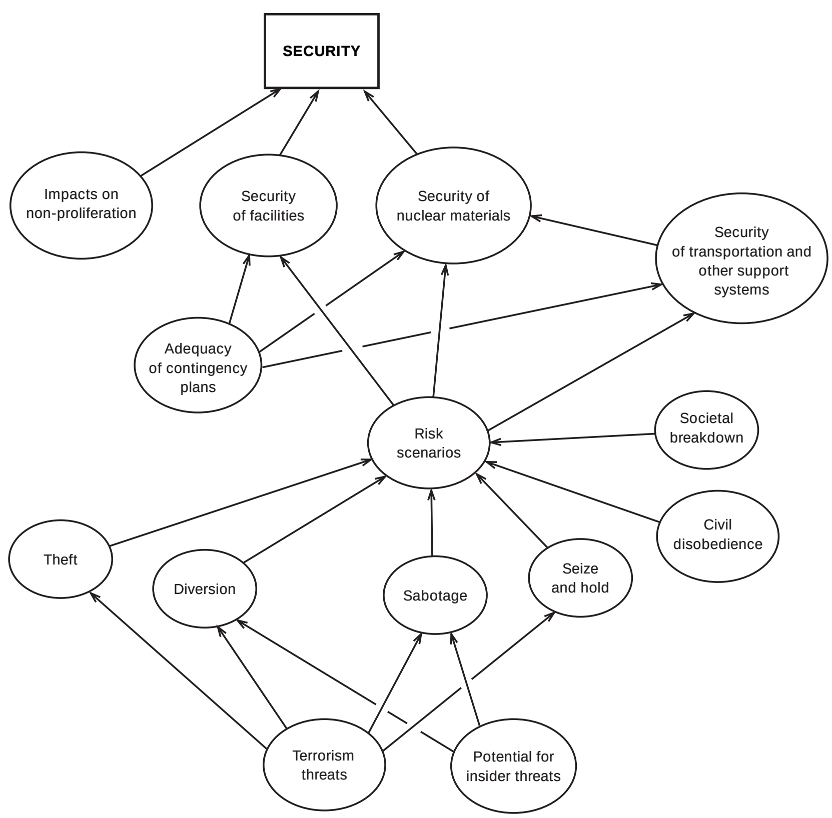


Table 3-5 Security

	BENEFITS	RISKS & UNCERTAINTY
Option 1: Deep Geological Disposal	Expected to perform well within the security requirements reflected in Canadian regulatory standards if built and operated as designed. In the near term, the high radioactivity of used fuel provides a "self-protecting" barrier against certain intruders. In combination with the heavy and large containers used to store used nuclear fuel in the interim period. Facility design and monitoring provide additional layers of further security. The size and weight of the heavy, large structures used for storing and transporting used fuel provide significant barriers to sabotage or theft. Once the used fuel is placed underground and the facility is backfilled and closed, the fuel is difficult to access, reducing the scope for theft, hostile intervention or dispersion of nuclear material. Even before closure, the limited access to the fuel and the 500-1,000 metre distance to surface provide considerable protection against security threats. Security is not reliant on ongoing active institutional oversight. An important feature for the long term, over which societal stability and institutional controls cannot be assured. Avoids the ongoing requirement for repackaging and handling and transportation once all the used fuel is placed in the deep repository (year 59), thereby limiting risks of security breaches and making the fuel significantly more secure for the longer term. Could be sited in location designed to limit security risk to the general population, for instance away from large population centres and with community involvement. Does not require repackaging of used nuclear fuel once all used nuclear fuel is placed in the repository (year 59).	Repackaging of used fuel, for transportation and perhaps placement in a deep repository, is required. However, substantially less repackaging of used fuel is required compared with storage options. Requires the identification and development of a site with potentially contentious community involvement. Public opposition to siting and transportation before confidence has been achieved may result in disruption in implementation and added security risk. Transportation risk and cost expected to be higher under conditions of low public confidence. Transportation to a central site would require additional safety measures for the movement of the used nuclear fuel from the nuclear reactor sites to the storage facility or facilities. 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-kilometers), depending on the illustrative economic region. Vulnerability of the used nuclear fuel is assumed to increase with increases in number of trip-kilometres. Therefore, there is a greater security risk during transportation for illustrative economic regions located longer distances from the majority of used nuclear fuel (i.e., longer distances from southern Ontario). For this approach, selection of any of the illustrative economic regions would involve 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 economic regions as with the other centralized approaches and thus have a similar degree of security risk for this measure in the near term.

Table 3-5 (cont'd) Security

	BENEFITS	RISKS & UNCERTAINTY
Option 2: Storage at Nuclear Reactor Sites	Expected to perform well within security requirements as reflected in Canadian regulatory standards if maintained and operated as designed. In the near term, accessibility of fuel is low, offering security protection. The high radioactivity of used fuel provides a "self-protecting" barrier which in combination with robust, heavy, large containers and structures used for storing used fuel provide significant barriers to sabotage or theft. In the near term, while nuclear plants continue operations, security is enhanced by security infrastructure already in place. Nuclear plants offer years of experience in protecting facilities from unauthorized entry/ access to fuel. With no requirements for off site transportation, this option avoids security risks associated with the transportation phase, and does not involve or require the cooperation of communities or the public outside of the host community.	After approximately 300 years, radiation levels decline such that the used fuel is no longer "self-protecting", making it more accessible to intruders. Managing the used fuel in surface facilities, at this point, requires significantly more physical protection resources than Options 1, 3 and 4 to ensure its long-term security. Security is heavily reliant on ongoing active management and institutional oversight and controls in perpetuity. Security risk could increase in the long term in the event of societal instability and resulting breakdown of institutional oversight. There is considerable uncertainty associated with the continuance of the societal infrastructure to ensure physical protection indefinitely. The level of the risk associated with a breakdown of institutional oversight, and complexity of managing it in the long term is compounded by the existence of seven sites, with several of the host economic regions including large population centres compared to a single central site. Requires ongoing repackaging of used fuel in perpetuity, providing future opportunities for security risk. Strong physical protection would be required during the periodic repackaging operations required every 100 years and lasting approximately 30 years for each repackaging operation. As many as 100 repackaging cycles could be required over a 10,000-year period. Over the long term, the benefit from co-location at nuclear plants and the opportunity to benefit from shared oversight facilities ceases once the nuclear plants are decommissioned. 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.

Table 3-5 (cont'd) Security

	BENEFITS	RISKS & UNCERTAINTY
Option 3: Centralized Storage	Expected to perform well within security requirements as reflected in Canadian regulatory standards if maintained and operated as designed. In the near term, the high radioactivity of used fuel provides a "self-protecting" barrier against intruders. This barrier continues for the first several hundred years. Facility design and monitoring provide additional layers of further security provision. Robust, heavy, large structures used for storing used fuel provide significant barriers to sabotage or theft. If central storage entails shallow underground storage, this offers an incremental security advantage over above ground facilities. Located at one central site, monitoring of the used fuel for the long term is facilitated, requiring fewer physical protection resources than would Option 2. Centralized storage, either above-ground or shallow below-ground, would allow for the site selection on the basis of used nuclear fuel management and its safe and secure management, for instance away from large population centres and with community involvement.	After approximately 300 years, radiation levels decline such that the used fuel is no longer "self-protecting", making it more accessible to intruders. Managing the used fuel in surface facilities, at this point, requires significantly more physical protection resources than Options 1 and 4 to ensure the long-term security of the fuel. Security is heavily reliant on ongoing active management and institutional oversight and controls in perpetuity. Security risk would increase in the long term in the event of societal instability and resulting breakdown of institutional oversight. There is considerable uncertainty associated with the continuance of the societal infrastructure to ensure physical protection indefinitely. Requires perpetual ongoing repackaging of used fuel indefinitely providing future repeating opportunities for security risk. Strong physical protection would be required during the periodic repackaging operations required every 100 years and lasting approximately 30 years for each repackaging operation. As many as 100 repackaging cycles could be required over a 10,000-year period. Requires the identification and development of a site with potentially contentious community involvement. Public opposition to siting and transportation before confidence has been achieved may result in disruption in implementation and added security risk. Transportation risk and cost expected to be higher under conditions of low public confidence. Transportation to a central site would require additional safety measures for the movement of the used nuclear fuel from the nuclear reactor sites to the central site. Total number of trip-kilometres required to transport all used nuclear fuel by road to a facility varies considerably (by up to 15 times the number of trip-kilometres), depending on the illustrative economic regions. Vulnerability of the used nuclear fuel assumed to increase in proportion to increases in number of trip-kilometres. Therefore, there is a greater security risk during transportation for illustrative economic regions located longer distances from the majority of used nuclear fuel (i.e. longer distances from southern Ontario). For this approach, selection of any of the illustrative economic regions would involve a similar number of large population centres (defined as greater than 50,000 inhabitants and based on available information) along transportation routes and thus have a similar degree of security risk for this measure in the near term.

Table 3-5 (cont'd) Security

	BENEFITS	RISKS & UNCERTAINTY
Option 4: Adaptive Phased Management	Expected to perform well within security requirements as reflected in Canadian regulatory standards if maintained and operated as designed. Accessibility of used fuel is low in both the near term and long term, offering protection from security breaches through hostile intrusion. In the near term, the high radioactivity of used fuel provides a "self-protecting" barrier against certain intruders. In combination with the heavy and large containers used to store used nuclear fuel in the interim period. Facility design and monitoring provide additional layers of security. The size and weight of the heavy, large structures used for storing and transporting used fuel provide significant barriers to sabotage or theft. The interim phase of shallow underground storage prior to proceeding to the deep repository, offers enhanced barrier for physical protection during storage in the period leading up to final placement in the repository. A secure form of storage is ensured in the interim period should there be a delay in placement in the repository. Over time, declining radiation fields reduce the potential consequences of sabotage in the event of a security breach, but reduce barriers to theft over time. For the long term, combination of engineered and natural geological barriers deep underground provide enhanced security. Multiple barriers protect the used fuel, through the fuel bundles, the containers and surrounding steel and concrete reinforcements, through to the robust rock in the geosphere. Once placed underground and the facility is backfilled and closed, the fuel is difficult to access, reducing the scope for theft, hostile intervention or dispersion of nuclear material. Even before closure, the limited access to the fuel and the 500-1,000 metres distance to surface provides considerable protection against security threats. Over the long term, security does not rely on ongoing active institutional oversight. An important feature for the long term, over which societal stability and institutional controls cannot be assured. Over the long term, avoids the ongoing requirement for repackaging and handling once all of the used fuel is placed in the deep repository, thereby limiting risks of security breaches and making the fuel significantly more secure for the longer term. Has the same high level of security in the long term as Option 1, as neither have repackaging events in the long term. Could be sited in location designed to limit security risk to the general population, for instance away from large population centres and with community involvement.	While offering more security than Storage at Nuclear Reactor Sites and Centralized Storage, the Adaptive Phased Management Approach is marginally less secure than Deep Geological Disposal in the Canadian Shield since it involves one additional repackaging of used fuel. As with Option 1 and Option 3, it would require additional safety requirements for the movement of the used nuclear fuel from the nuclear reactor sites to the storage facility or facilities. Total number of trip-kilometres required to transport all used nuclear fuel by road to a facility varies considerably (by up to 15 times the number of trip-kilometres), depending on the illustrative economic regions. Vulnerability of the used nuclear fuel is assumed to increase in proportion to number of trip-kilometres. Therefore, there is a greater security risk during transportation for illustrative economic regions located longer distances from the majority of used nuclear fuel (i.e. longer distances from southern Ontario). For this approach, selection of any of the illustrative economic regions would involve a similar number of large population centres (defined as greater than 50,000 inhabitants and based on available information) along transportation routes and thus have a similar degree of security risk for this measure in the near term. Requires the identification and development of a site with potentially contentious community involvement. Public opposition to siting and transportation before confidence has been achieved may result in disruption in implementation and added security risk. Transportation risk and cost expected to be higher under conditions of low public confidence. However, this approach provides for a longer period over which to build and establish confidence.

Summary Findings

All four options, if built and operated as designed, are expected to perform well within the security requirements of Canada's regulatory standards. Many aspects of security have been examined over the course of our analysis. Five particular aspects are briefly discussed below.

i) Fuel Accessibility

The less accessible the fuel, the stronger the contribution to ensuring the nonproliferation of weapons useable material. Access to the used fuel can be reduced by the actions of institutions, and the security mechanisms that they put in place and maintain, and through engineered and geological physical barriers that prevent access to the fuel.

Option 1 and Option 4, because they involve placing used nuclear fuel deep underground, and ultimately backfilling and sealing all routes to access the fuel, are inherently more secure than Option 2 and Option 3 over the long term. These two latter storage options keep and manage used nuclear fuel at or near the surface and rely upon security mechanisms in the form of robust containers and security fencing and personnel to prevent access. The storage of used fuel at or near the surface inherently poses additional security risk and demands additional security precautions. Security is heavily reliant on ongoing institutional management and controls, in perpetuity. Uncertainty over the availability of institutions and controls increases over time.

ii) Number of Repackaging Cycles

Repackaging of used nuclear fuel presents some risk of hostile attack for all four approaches. However, Option 1 and Option 4 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 Option 2 and Option 3, which require as many as 100 repackaging cycles over the 10,000-year assessment period.

While offering more security than Option 2 and Option 3, Option 4 is marginally less secure than Option 1 since it involves one additional repackaging event.

iii) Robustness of Physical Barriers

Of the four approaches, Options 1 and 4 offer the strongest physical protection of the used fuel and the management facilities against unintended security breaches through inadvertent intrusion or unauthorized intrusion. The combination of robust engineered barriers built into the design, the selection of the site, together with the geological barriers associated with placement of the fuel deep underground, is expected to enable secure isolation of the used fuel both in the near term and the long term. Protection against disruption or breaching of the barriers by intrusion is provided through these many barriers that isolate the used fuel, and is not reliant on ongoing effective institutional controls and active societal oversight over the very long term.

Of these two approaches, Option 4 offers additional advantages in that implementation allows for interim steps at each stage and contingency plans to ensure the security of the material should implementation not proceed as planned. Specifically, it allows for a centralized shallow underground storage facility in the period preceding the deep repository. The possibility of such intermediate steps would allow for timely centralization of the used fuel to a safe storage facility under ground, while allowing for building confidence before transporting and emplacing the fuel in the final repository.

Option 4 has the same number and robustness of physical barriers as Option 1 following facility closure in Year 325 and 154, respectively.

iv) Transportation Distance

Transportation of used nuclear fuel involves some inherent risk to security, although this risk is judged to be small. Option 2 requires no off-site transportation of used nuclear fuel, that is, there are no opportunities for attempted dispersion during transportation.

The options that require transportation to a central site, Option 1, Option 3 and Option 4, would require additional safety requirements for the movement of the used nuclear fuel from the nuclear reactor sites to the storage facility of facilities. For these three options, total number of trip-kilometres required to transport all used nuclear fuel by road to a facility varies considerably (by up to 15 times), depending on the illustrative economic region. Vulnerability of the used nuclear fuel is assumed to increase with the distance traveled.

Environmental Integrity Analysis

Our objective:

To ensure environmental integrity.

The selected management approach needs to ensure that environmental integrity is maintained over the long term. Concerns include the possibility of localized or widespread damage to the environment 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).

Assessing the degree of impact each approach would have on the natural environment required consideration of many factors, including the number and sensitivity of ecosystem elements that would potentially be affected, the likelihood of impact to each type of resource, and the significance of the potential consequences to affected resources. Many different types of valued and environmentally sensitive resources could be affected, including plants and animals, land, surface water, groundwater and the air (e.g., through air pollution created during the construction of a new facility). Also included in the assessment were various aesthetic impacts, such as noise, and visual changes to the natural scenery. As in the case of other objectives, it is necessary to consider not only the stresses that each approach would produce assuming that the approach performs as expected, it is also necessary to consider the possibility of "off-normal" risk scenarios. The complete list of influences considered is expressed in the influence diagram below.

It is difficult to precisely forecast the environmental impacts of the various approaches. This is especially true in the cases of the geological repository and centralized storage approaches because the impacts of each approach depend greatly on where the new facilities would be located, something that is not yet known. The long time-frames involved complicate forecasts for all approaches.

Comparative Assessment

Table 3-6 presents our assessment of the relative benefits and risks and uncertainty for each of the four options studied.

Figure 3-7 Environmental Integrity Influence Diagram

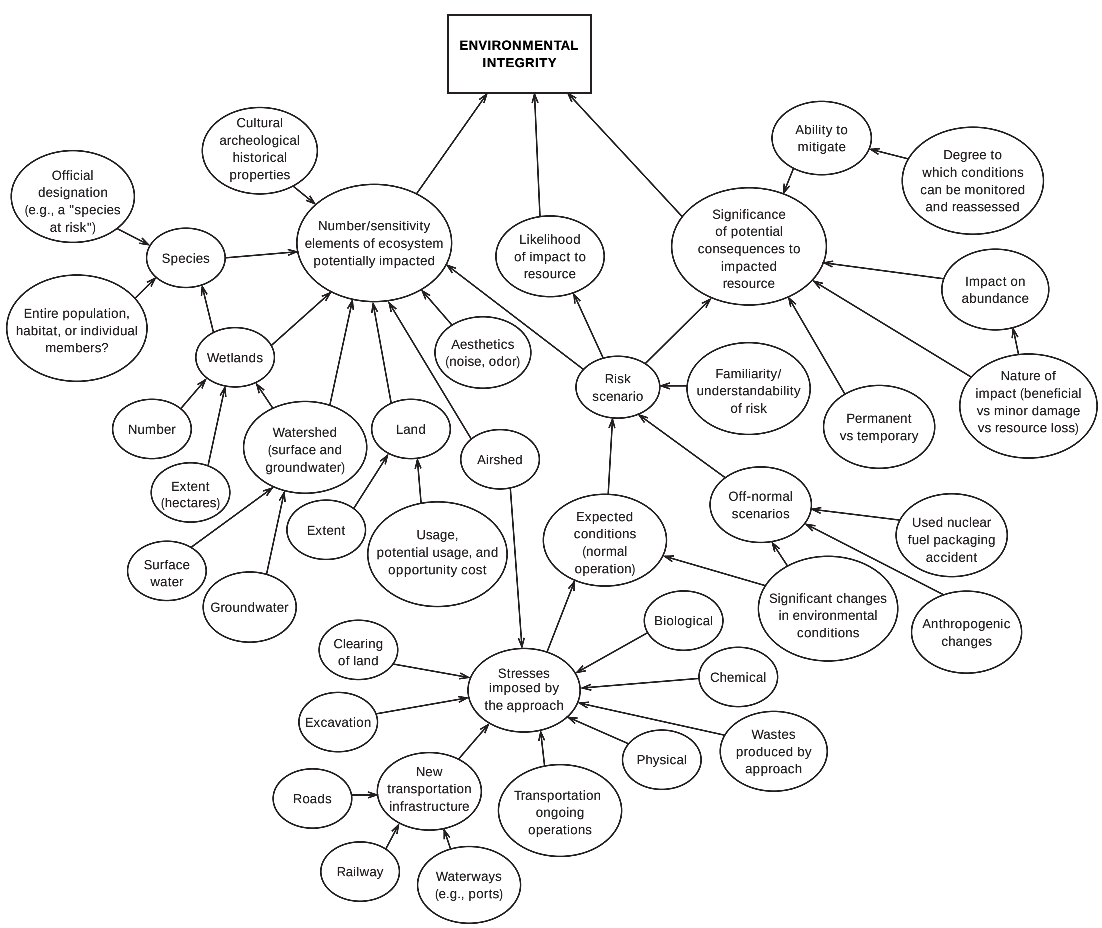


Table 3-6 Environmental Integrity

	BENEFITS	RISKS & UNCERTAINTY
Option 1: Deep Geological Disposal	Under normal conditions, this approach is expected to be able to 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. This method is considered to deliver benefits over the very long term, since the used fuel is isolated from the environment. Provides significant advantages over surface-based facilities (Options 2 and 3) with respect to withstanding the effects of major environmental changes over the long term. The deep repository, isolated from surface water systems, provides a strong barrier against possible environmental events. Used fuel is placed deep underground. Once the facility is closed, it is not reliant on active management to ensure safety. With the multiple and robust barriers, the engineered facility together with the geological barrier of granitic rock, are designed to isolate the fuel securely, away from the environment, providing low likelihood of an adverse environmental effect. The resilience of this management approach in providing a high level of protection of the environment is particularly critical in light of possible climatic changes and extreme natural events that may well be associated with the tens of thousands of years over which the used fuel must be managed. Some long-term environmental changes may be gradual, such as effects of climate change and rising surface water levels. Other effects may be episodic, such as earthquakes and seismic activities. Resilience of the facilities must also be considered for glaciation. Avoids the need for periodic repackaging of used fuel and associated risks to the environment. The site can be chosen to minimize environmental impact.	In the short term, the construction of the facility could produce adverse impacts on the environment. These impacts are expected to be localized and relatively short lived. Following closure of the repository, after year 154 approximately, monitoring for potential environmental effects becomes more difficult than with surface based facilities. However, likelihood of an adverse effect occurring even over the long term is low because of the physical and geological barriers built into this facility design. Used fuel retrieval or other corrective action is also difficult. Advance "proof" that such a system works is not scientifically possible because performance is required over thousands of years. Detailed scientific studies, models and codes and natural analogues form the foundation of the assurances of performance. Requires transportation of the used fuel to the central facility over a 30-year period. With likelihood of transportation accidents low, transport is unlikely to carry with it large risks to the environment. The transportation routes would likely traverse multiple ecozones. In addition, risks associated with transportation would be lowest for illustrative regions that are located closest to the current reactor sites.

Table 3-6 (cont'd) Environmental Integrity

	BENEFITS	RISKS & UNCERTAINTY
Option 2: Storage at Nuclear Reactor Sites	Under normal conditions, this approach is expected to be able to 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. Provides a robust management approach in the near term (first 175 years). Risk of occurrence of off-normal events is low in the near term. Avoids the construction of a deep repository and the potential environmental disruption associated with implementation. Also avoids involvement of a new potentially greenfield site. With facilities at or near surface, provides for ease of monitoring of facility performance. Any environmental problems that develop are more readily identified and addressed. No transportation of used nuclear fuel would be required, as the used fuel would remain where it is generated. The science and technology required are well in-hand.	Protection of the environment for the long term is uncertain given that effective performance requires strong institutional control and oversight, and that is uncertain over the long term. Since the facilities are constructed at or near surface, they are unlikely to be able to withstand glacial events or major long-term environmental disruption from extreme weather events or other major climatic changes. With safety of the site reliant on ongoing active institutional control, social instability that jeopardizes monitoring and oversight, or leaves the site abandoned, would introduce significant environmental risk. These risks multiply in the long-term, with uncertainty over environmental patterns that may unfold over the tens of thousands of years for which the fuel requires isolation. Long-term risks are compounded, in light of the multiple (seven) sites at which facilities would exist. 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.
Option 3: Centralized Storage	Under normal conditions, this approach is expected to be able to 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. Provides a robust management approach in the near term (first 175 years). Risk of occurrence of off-normal events is low in the near term. Avoids the construction of a deep repository and the environmental disruption associated with implementation. With facilities at or near surface, provides for ease of monitoring of facility performance. Unanticipated problems are more readily identified and addressed. Offers better and more predictable environmental performance than Option 2 both in near term and long term. One centralized facility reduces the range of environmental resources at risk. Siting of the new facility allows for it to be purposely located and built in such a way as to reduce environmental risks. The required science and technology are well in hand for the above ground storage design.	Protection of the environment for the long term is uncertain given that effective performance requires strong institutional control and oversight, and that is uncertain over the long term. The construction of the facility could produce adverse impacts on the environment. Since the facility is to be constructed at or near surface, it is less likely to withstand glacial events or major long-term environmental disruption from extreme weather events or other major climatic changes without active institutional management. Below ground storage offers some advantages compared with surface facilities. With safety of the site reliant on ongoing active institutional control, social instability that jeopardizes monitoring and oversight, or leaves the site abandoned, would introduce substantial environmental risk. These risks multiply in the long-term, with uncertainty over environmental patterns that may unfold over the tens of thousands of years for which the fuel requires isolation. Requires transportation of the used fuel to the central facility over a 30-year period. With likelihood of transportation accidents low, transport is unlikely to carry with it substantial risks to the environment. In addition, risks would be the lowest for illustrative regions that are located closest to the current location of the majority of the fuel.

Table 3-6 (cont'd) Environmental Integrity

	BENEFITS	RISKS & UNCERTAINTY
Option 4: Adaptive Phased Management	Under normal conditions, this approach is expected to be able to 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. It allows a period of time of high flexibility in which new learning might be easily incorporated. It allows for decisions to be reversed, should this be required, and provides for a viable, safe and secure storage capability at each point in the process, even should there be delay before proceeding to the next stage of implementation. Over the long term, when most uncertain, not relying on ongoing institutional control of the facility, avoids risks that might otherwise be posed in the event of long-term societal instability. Being located deep underground, the radioactive materials would be contained and isolated from the environment. In the deep repository, the used fuel is protected by both robust natural barriers provided by the crystalline or sedimentary rock, as well as the engineered barriers in terms of container design, buffer materials, etc. Facility could be expressly sited and designed to minimize environmental impact. Extended implementation period allows more time to understand the environmental conditions through research at the underground research laboratory and with the used fuel placed in the shallow rock caverns, before making the decision to move the fuel into the deep repository for long-term isolation. Over the decades of program development and implementation, the selected approach will encounter changes in society, technology, economics, and the environment. These changes are better accommodated by this adaptable approach.	In the short term, the construction of the facility could produce adverse impacts on the environment as the shallow storage in rock caverns is built, and later the deep repository is built at a depth of 500-1,000 metres under ground. These impacts are expected to be localized and relatively short lived, compared with the storage options. The above ground facilities are less likely to withstand severe environmental events, however it is expected that such events are very unlikely during the period of above ground storage envisioned in this approach. These above ground facilities would require active institutional control, however social stability is expected to continue through the period of above ground storage envisioned by this approach. The interim step of shallow storage at a single purpose built site will enhance robustness and surety of performance towards the end of this period. Following closure of the repository, at a time when society makes that decision, which is expected to be on or before year 325, monitoring for potential environmental effects becomes more difficult than with surface based facilities. However, likelihood of an adverse effect occurring even over the long term is low because of the physical and geological barriers built into this facility design. The extended period of technology development and testing is expected to increase the performance of the system and confidence in its performance. Requires transportation of the used fuel to the central facility. With likelihood of transportation accidents low, transport is unlikely to carry with it large risks to the environment. The transportation routes would likely traverse multiple ecozones. In addition, risks associated with transportation would be lowest for illustrative regions that are located closest to the current reactor sites.

Summary Findings

Under normal conditions, all four management approaches are expected to be able to be constructed and operated without causing significant adverse effects on the environment in the near and long term. This is achieved by implementing standard and proven mitigation measures and best management practices. For all options, a more detailed examination of environmental impacts will be required once potential sites have been identified.

The multiple barriers associated with Options 1 and 4, as discussed under "Public Health and Safety" also apply to environmental integrity. Site selection, engineered barriers and placement at depth in geologic media comprise robust management designs to protect environmental integrity. The performance of these barriers is not reliant on ongoing societal oversight to offer protection over the long term. A further benefit of Option 4 is the extended interim period over which the site and the facilities can be monitored, tested and refined, prior to final placement of the used fuel. This opportunity for active monitoring and study will allow us to learn, understand and adjust facility designs as may be appropriate over a staged implementation period.

Storage approaches, Options 2 and 3, offer the benefit of easy monitoring and access to the fuel to address any detected impacts. In the long term, however, these options introduce long-term risks. Monitoring and securing of the facilities is reliant on active institutional management and controls, over a time period in which we cannot be assured of ongoing social stability as we know it today. Facilities sited at or near surface are also expected to be less resilient to long-term climatic changes and environmental conditions than facilities secured deep underground.

Economic Viability Analysis

Our objective:
To design and implement a management approach that ensures economic viability of the waste management system, while simultaneously contributing positively to the local economy.

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

Assessing the economic viability of the approaches required considering the likelihood that financial resources would be available to pay the costs, recognizing that these costs are uncertain and, especially in the case of the reactor site and centralized storage approaches would continue over a very long time. The complete list of influences considered is depicted below.

Comparing Costs Against Management Approaches

As part of the comparative assessment, the *NFWA* requires that we compare the costs across management approaches.

In the table below, we present the total (undiscounted) costs for each management approach. In addition, we provide the present value cost for each management approach.

Cost estimates for Options 1, 2 and 3 were developed through work commissioned by the Joint Waste Owners – Ontario Power Generation Inc., Hydro-Québec, NB Power Nuclear, and Atomic Energy of Canada Limited. The Joint Waste Owners commissioned engineering consulting firms to develop preliminary conceptual engineering designs for the three technical methods identified in the *Nuclear Fuel Waste Act*, and also to develop associated transportation infrastructure and cost estimates for those designs.

For each option specified in the *NFWA*, preliminary cost estimates were commissioned for siting, construction, operation, monitoring, closure and where applicable, closure and decommissioning of nuclear waste management facilities and for the transportation of used nuclear fuel. (www.nwmo.ca/costsummaries)

Figure 3-8 Economic Viability Influence Diagram

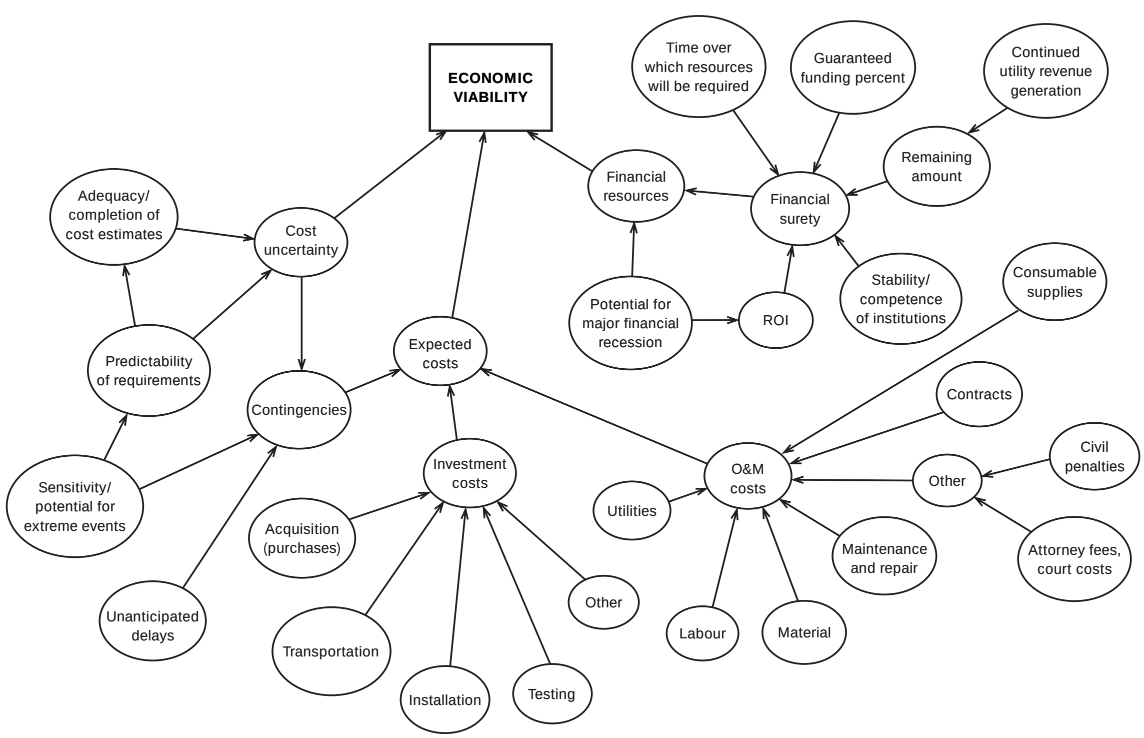


Table 3-7 Costs Estimates for Management Approaches

Management Approach	Total Cost (2002B$) (out to 350 years)	Total Cost (2002B$) (out to 1,000 years)	Present Value (Jan 2004 B$)
Option 1: Deep Geological Disposal in the Canadian Shield	16.2	16.3	6.2*
Option 2: Storage at Nuclear Reactor Sites			
Current Technology	17.6		2.3
New Above Ground Technology	25.7	68.4	4.4
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	46.9	3.8*
Cask/Vaults in Shallow Trenches	18.7		3.6
Casks in Rock Caverns	17.1	40.6	3.4*
Option 4: Adaptive Phased Management			
With Shallow Underground Storage	24.4	24.4	6.1*
Without Shallow Underground Storage	22.6	22.6	5.1*

JWO estimates are based on 3.7 million fuel bundles and an average reactor life of 40 years. Golder estimates are based on 3.6 million fuel bundles.
Estimates for Options 1, 2 and 3 out to 350 years were prepared by consultants for the Joint Waste Owners (www.nwmo.ca/costsummaries).
Estimates for Options 1, 2 and 3 out to 1,000 years were prepared by Golder Associates Ltd. and Gartner Lee Ltd. (www.nwmo.ca/assessments).
Estimates for Option 4 were prepared by Golder Associates Ltd. and Gartner Lee Ltd. (www.nwmo.ca/assessments).
* Present value calculations performed by Golder Associates Ltd. and Gartner Lee Ltd., are for 1000 year total estimates.
All remaining present value figures were taken from Joint Waste Owners cost estimates using 350 year total cost estimates.
Note: 1000 year cost estimates were produced from an illustrative sample of all possible management approaches, for comparative purposes only.

We commissioned a third-party review of this body of work for Options 1, 2 and 3. We asked independent consultants to examine the key engineering design assumptions and cost estimation process. (www.nwmo.ca/engineeringreview) Their observations and conclusions were:

- All of the conceptual designs are credible, technically feasible and suitable for the intended purpose, which is to assess the options and arrive at a recommended approach;
- The conceptual designs are well developed and documented, and prepared in a manner consistent with established engineering practice;
- Design details are consistent with the conceptual nature of the work and there is no reason to suspect that an appropriate final design could not be developed for an approach selected from the designs reviewed; and
- Although the conceptual designs are conservatively sized and limited to the CANDU fuel inventory from existing reactors, they have the flexibility to provide increased used fuel storage capacity in the future, by building either incremental additions or completely new facilities.

The third-party review of the cost estimates for Options 1, 2 and 3 concluded that they have been prepared with an appropriate estimating methodology and are suitable for the options review and directional decision-making requirements of the NWMO. (www.nwmo.ca/costreview)

The conceptual designs and related cost estimates, reviewed by independent third parties, were found to be sufficient for our objectives. Specifically, the review of cost estimates included a professional opinion that the accuracy of these estimates was assessed as being within the range of plus and minus 33 percent including all the contingency allowances. These estimates were considered suitable for their purpose in assessing the magnitude of the cost of the scenarios and their alternatives.

Based on this work, we have adopted these cost estimates for Options 1, 2 and 3, which we believe to represent thorough and reasonable cost estimates for the options based on the conceptual stage of design. A cost estimate for Option 4 was created through extracting costs from like activities from Options 1, 2 and 3.

Cost estimates provide for:

- Public Health and Safety. 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 among economic regions;

- Worker Health and Safety. Some costs for worker safety, including radiation protection and conventional occupational health and safety protection, are accounted for in the economic costs of all management approaches through facility designs and monitoring programs;

- Security. Some costs for security are accounted for in the economic costs of all four approaches through facility designs and monitoring programs;

- Environment. Some costs for environmental integrity are accounted for in the economic costs of the management approaches through facility designs and monitoring programs;

- Citizen engagement. Costs for public engagement and consultation are provided for in the cost estimates;

- Research. The cost estimates include provision for ongoing research; and

- Transportation costs. The incremental transportation costs for Option 1: Deep Geological Disposal in the Canadian Shield, Option 4: Adaptive Phased Management; and Option 3: Centralized Storage (above or below ground) have a similar range, and vary across economic regions by up to about $1 billion (2002 dollars, not discounted). Incremental transportation costs are greater for economic regions located farther from the majority of the used nuclear fuel, which is in southern Ontario. There are no transportation costs associated with Option 2: Storage at Nuclear Reactor Sites. A representative transportation cost for the other three approaches is in the range of $1.2 billion (2002 dollars, undiscounted).

The cost estimates used in evaluating each of the studied management approaches were prepared at a conceptual level, and do not include specific allocations for all labour requirements, ancillary facility operations or physical retrieval of placed fuel. The cost estimates include a contingency of approximately 20 percent, to cover possible changes in concept implementation. More detailed conceptual designs and cost estimates will be prepared during the normal course of implementation following a decision by the Government of Canada.

These cost estimates and a more detailed discussion of provisions for financial surety are provided in Chapter 18.

We have reported on costs in two ways: present value and undiscounted total costs. Both convey key information for understanding the economic aspects of each option.

For purposes of defining funding requirements an acknowledged and accepted practice is based on the use of present value estimates.

For purposes of understanding socio-economic impacts, it is instructive to also look at the undiscounted cash-flow profiles for each management approach. In examining the projected timing and repeat cycles of investments associated with building, refurbishing and maintaining a facility, we can appreciate the magnitude of socio-economic impacts on communities from the project over time. This helps us to anticipate and plan for the benefits and challenges associated with managing those cyclical changes within the community hosting the facility.

By comparing the present value costs for each management approach, the current users of nuclear generated electricity are taking the appropriate steps to ensure that each management approach is funded in such a way as to minimize the financial burdens of future generation. Saving funds for a conservatively modeled set of costs increases the adaptive capacity of the management approach over the life of the project and enhances generational fairness.

In the four figures below, we illustrate the undiscounted cash-flow profiles for each management approach to Year 1000. These cash flows do not include costs for interim storage, retrieval and transportation.

Figure 3-9 **Total Cash Flow Option 1: Deep Geological Disposal in the Canadian Shield (less costs for interim storage, retrieval and transportation)**

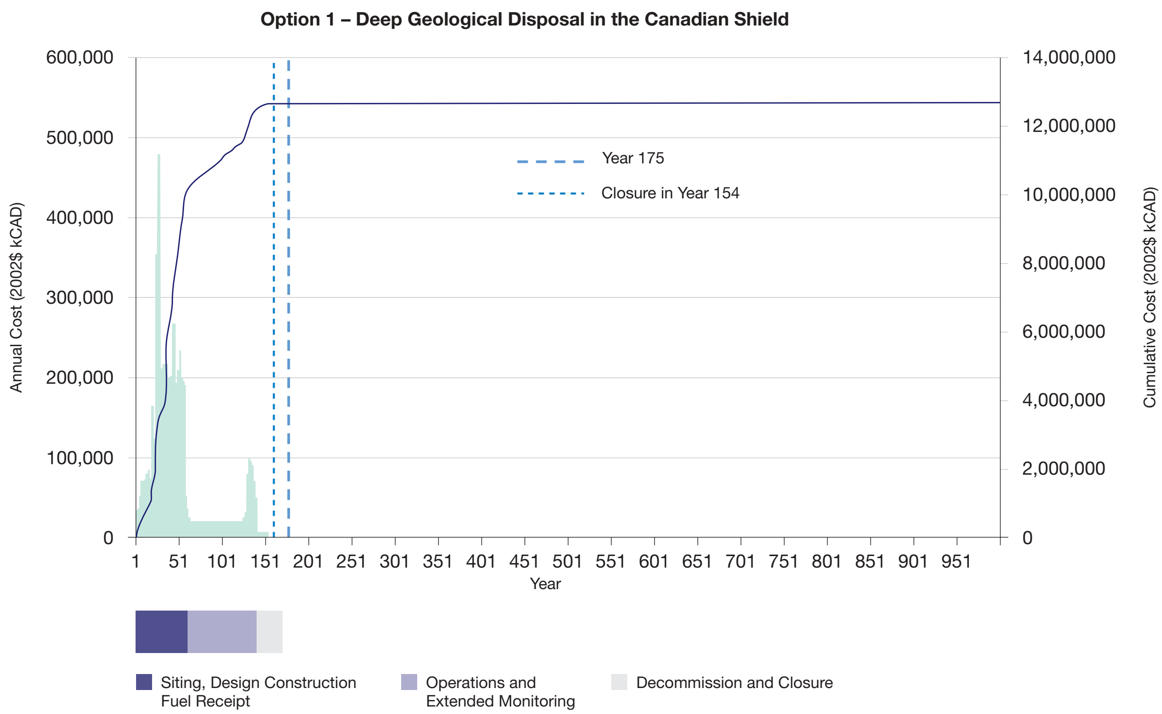


Figure 3-10 **Total Cash Flow Option 2: Storage at Nuclear Reactor Sites**

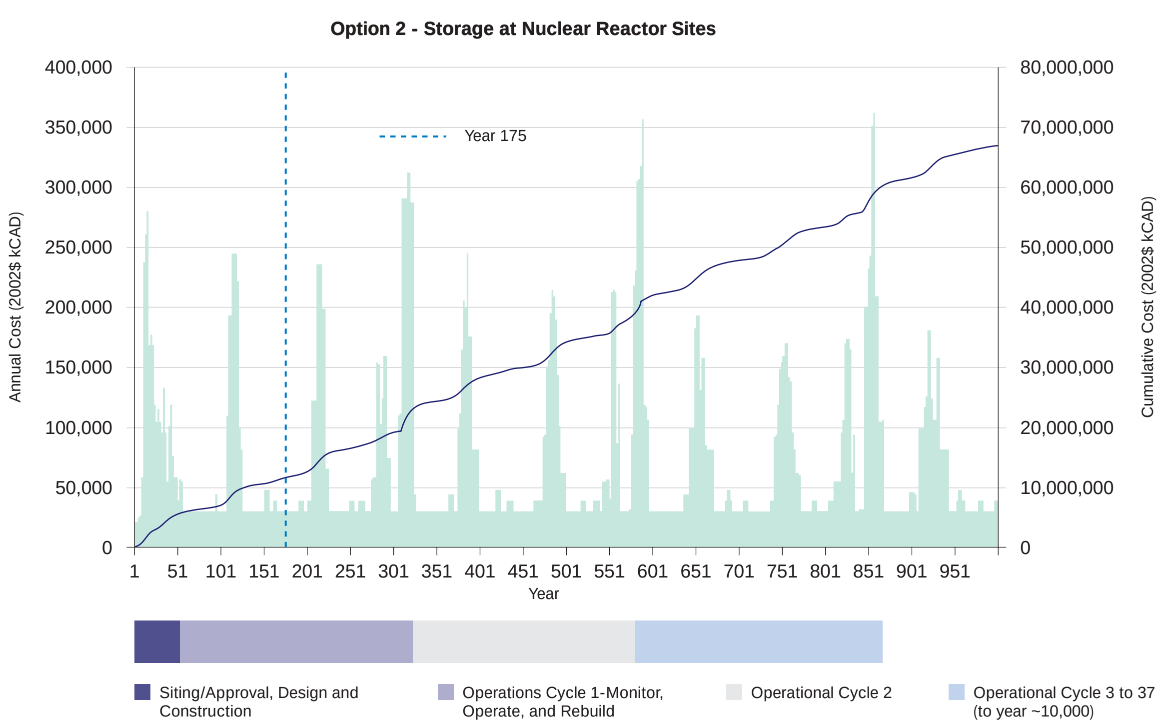


Figure 3-11 **Total Cash Flow Option 3: Centralized Storage (Above Ground) (less cost for interim storage, retrieval and transportation)**

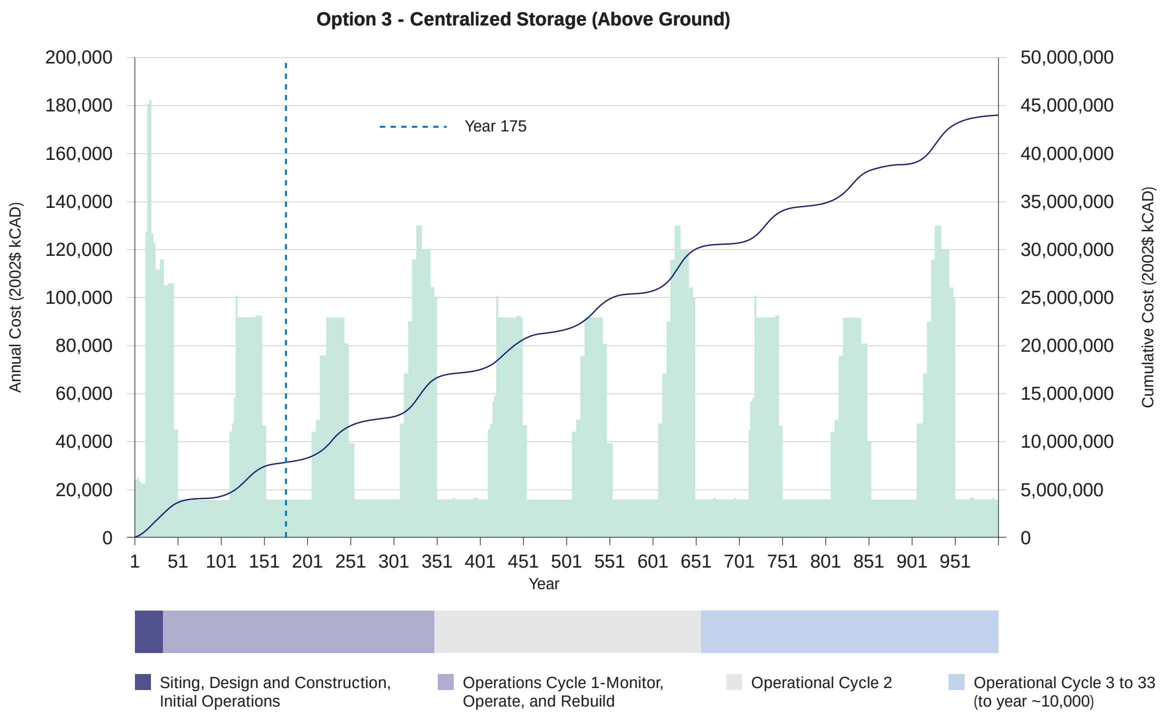
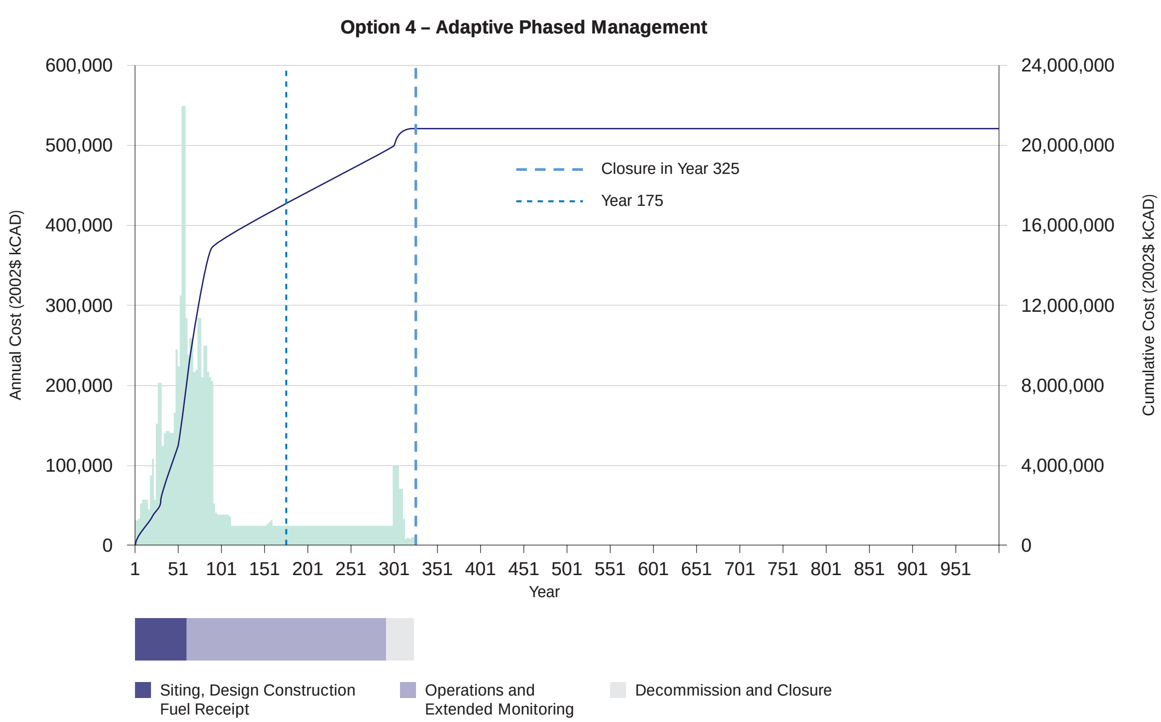


Figure 3-12 **Total Cash Flow Option 4: Adaptive Phased Management (less cost for interim storage, retrieval and transportation)**



- Option 1: Deep Geological Disposal in the Canadian Shield has the highest short-term cumulative cost ($10.1 billion in 2002 dollars, not discounted), up to Year 59, the time when all facilities (for all four approaches) are filled with used nuclear fuel, while Option 3: Centralized Storage (below ground) has the lowest cumulative cost ($2.6 billion in 2002 dollars, not discounted) for the same period.

- Option 4: Adaptive Phased Management has the highest cumulative cost ($16.95 billion in 2002 dollars, not discounted) up to Year 175 while Option 3: Centralized Storage (below ground) has the lowest cumulative cost ($6.6 billion in 2002 dollars, not discounted) for the same period.

- Option 2: Storage at Nuclear Reactor Sites has the highest cumulative cost ($67 billion in 2002 dollars, not discounted) up to Year 1,000 (i.e., the "long-term" period selected for this study – see Section 2.5.1), while Option 1: Deep Geological Disposal in the Canadian Shield has the lowest cumulative cost ($12.7 billion in 2002 dollars, not discounted) over the same period.

Comparative Assessment

Table 3-8 presents our assessment of the relative benefits and risks and uncertainty for each of the four options studied.

Table 3-8 Economic Viability

	BENEFITS	RISKS & UNCERTAINTY
All approaches		Long-term management costs for the approaches (i.e., costs out to hundreds to thousands of years and beyond) are based on current technology costs and assumptions regarding 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 today's 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 initially put the used nuclear fuel in place in a facility for any of the four approaches. During final design, siting, environmental assessment and licensing, modifications to the design or schedule could result in significant cost increases. For example, the licensing and approval process, add-ons, more restrictive standards and other possibilities unforeseeable to the designers may lead to costs in excess of original estimates and the allowable contingencies, although the contingencies which are provided for in the cost estimate are comparable or greater than those for comparable projects.
Option 1: Deep Geological Disposal	Higher initial costs and lower longer term costs provide greater financial surety. With respect to time dependence of estimate certainty and the provision of surety, this option has the most certain estimates, as the vast majority of costs would be incurred in the near term. It is also the easiest to develop surety for because the facility closes in Year 154. If one is only concerned about the ability to marshal the necessary financial resources to complete the management of used nuclear fuel, this method is best. This management approach places used fuel in a "final" state with relatively little financial requirements over the very long-term compared with the two storage options. This means that the burden of financial surety is placed mostly in the hands of the current generation. Provides higher confidence that funding shortfalls will not occur that would threaten the assured continuation of necessary operations compared with the two storage options.	Although the burden of financial surety is placed mostly in the hands of the current generation, should new technologies arise or should other social and/or technology issues arise, then future generations may be burdened with our used nuclear fuel legacy to an even greater extent. Since this type of facility has not been previously constructed, there is potential for problems and delays, which would raise costs. The incremental transportation costs 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). The potential incremental transportation costs are significant compared with the cost of the management approach in the near term.

Table 3-8 (cont'd) Economic Viability

	BENEFITS	RISKS & UNCERTAINTY
Option 2: Storage at Nuclear Reactor Sites	There is more certainty over near-term costs because a modified version of the technology is known and currently used. No costs associated with off-site transportation.	Lower initial costs, and higher longer-term costs, create more uncertainty around financial surety. The cost estimates provided for storage approaches have a higher degree of uncertainty than those for Option 1 because they assume conditions far in the future. Although the current generation will set aside funds for the long-term management of the used fuel, this method imposes a liability on future generations for continued active management and appropriate oversight institutions and a burden to cover costs that are not anticipated and funded today. The need for major rebuilding operations on a regular basis in perpetuity severely limits the current generation's ability to estimate costs and provide surety. Cost estimates are more uncertain the farther into the future they are projected. Uncertainty with respect to surety also increases.
Option 3: Centralized Storage	There is more certainty over near-term costs because the technology is known and currently used.	Lower initial costs, and higher longer-term costs, create more uncertainty around financial surety. The cost estimates provided for storage approaches have a higher degree of uncertainty than those for Option 1 because they assume conditions far in the future. Although the current generation will set aside funds for the long-term management of the used fuel, this method imposes a liability on future generations for continued active management and appropriate oversight institutions and a burden to cover costs that are not anticipated and funded today. Although the approach might be less costly initially, there are significant uncertainties. There would be substantial costs incurred in finding and characterizing a site. Transport costs may be significant, and could increase if there are major delays. There would continue to be significant cost requirements going into the future associated with ongoing maintenance and periodic refurbishment of the facility. The need for ongoing repackaging and rebuilding operations on a regular basis in perpetuity severely limits the current generation's ability to estimate costs and provide surety. Cost estimates are more uncertain the farther into the future they are projected.

Table 3-8 (cont'd) Economic Viability

	BENEFITS	RISKS & UNCERTAINTY
Option 4: Adaptive Phased Management	Higher initial costs, and lower longer-term costs provide more financial surety. Adequate surety can be developed. Examples exist of select human organizations and their investments persisting for over 325 years and this approach provides for a long-term storage facility based on existing, passive technologies rooted in long-standing areas of human activity (mining, metallurgy). The approach 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. It preserves opportunities for decision making to future generations up to year 325 without compromising the responsibility of the current generation to provide for a long-term solution.	Spans a longer time period than Option 1, which increases risk of financial surety, but a much shorter period of time than Option 2 and Option 3 with, therefore, comparative greater expectation of financial surety. There could be substantial costs incurred in finding and characterizing a central site. Transportation costs may be significant.

Summary Findings

All options require substantial funding to be provided by the owners of nuclear waste. In all cases, the *NFWA* would require contributions from each nuclear corporation against an approved funding formula and schedule, thus ensuring as much as possible that the generation that benefited from the nuclear power also sets aside the required amounts to fund the approach.

The options are differentiated by significant variation in cost (either total cost or present value). The options are differentiated by the timing of expenditures in both the near and long term.

The options are differentiated by the uncertainty associated with estimating the amount of funds required and ability to protect these funds to ensure availability for this purpose over the very long time period over which the approach requires expenditures.

Options 1 and 4 are judged to offer the most surety, requiring the majority of expenditures to be made in the near term (within the first 100 years). Over this period, we believe it is reasonable to be confident in the availability of strong institutions and, therefore, safekeeping of the funds that have been contributed for this purpose. Confidence is also higher since the period for which costs need to be estimated is shorter.

In contrast, Options 2 and 3 are judged to offer the least certainty both that estimates made now will be accurate for the long duration of implementation involved with these approaches and that funds set aside now can be protected for this purpose for the long period that they are to cover. This is because these approaches require used fuel repackaging and rebuilding of storage facilities every 100 to 300 years in perpetuity. Funding would need to be assured on an ongoing basis to support the refurbishment and maintenance that is essential to securing the safe storage of the used fuel. Looking out to the long term, over the thousands of years for which the fuel must be isolated from the environment, we face considerable uncertainty that introduces risk to financial surety. Over the long term we cannot predict the performance of financing instruments or the status of the financial and governmental institutions responsible for the safekeeping of the funds.

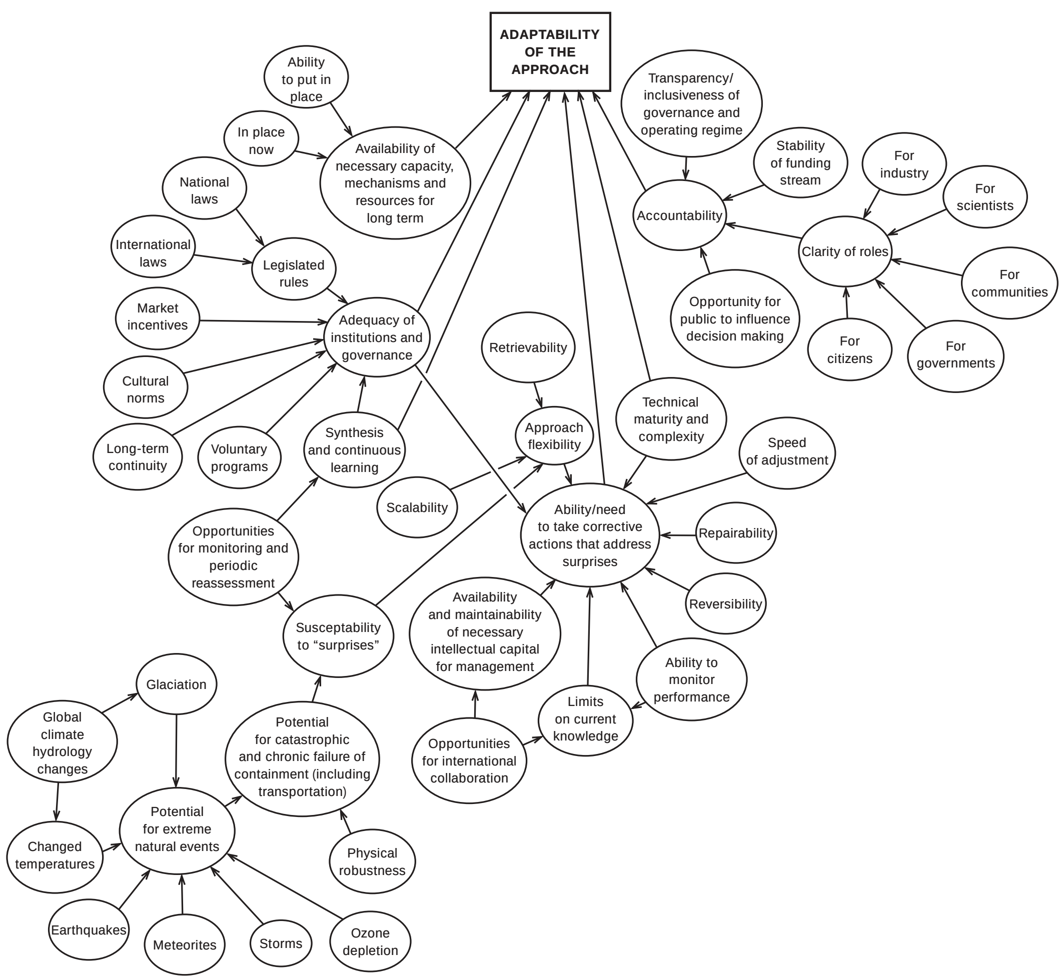
Adaptability Analysis

Our objective:
To ensure a capacity to adapt to changing knowledge and conditions over time.

The selected management approach should be robust in the face of new or unforeseen circumstances. The approach should provide flexibility to future generations to change decisions; not place burdens or obligations on future generations that will constrain them. The approach should be able to function satisfactorily in the case of unforeseen events.

There was much discussion on this objective by citizens during the dialogue following release of our second discussion document. Although there appeared to be broad agreement on the importance of this objective, some debate was raised concerning how best to characterize or define the objective. Should the adaptability of an approach be defined primarily on the basis of the flexibility in future decision-making that it provides? Should the adaptability of an approach be defined primarily on the basis of the robustness it provides in the face of changing environmental conditions?

Figure 3-13 **Adaptability Influence Diagram**



We have proceeded in a way which understands that both of these are potentially important influences on the adaptability of a management approach even though the measures one might put in place to achieve flexibility might directly conflict with the measures one might put in place to achieve robustness. What is required to make an approach adaptable in the near term may not be the same as what is required to make an approach adaptable in the very long term. Given the long time-frames for which any management approach will need to effectively contain and isolate used nuclear fuel, the balancing of such tensions is integral to both understanding what adaptability means for this issue and assessing the approaches on it.

We have approached adaptation as a general strategy of systems for attaining or maintaining a goal in the face of changing environmental circumstances. "Adaptability" is here defined as the set of characteristics of an option that are expected to make a management approach robust with respect to the widest range of possible social and environmental scenarios in the long-term future. To be "adaptable" is to be capable of responding well to changes in environmental and social conditions, over a wide range of such possible changes.

Assessing the adaptability of each approach required consideration of many factors, including whether there are opportunities to adapt to changing knowledge or circumstances during the period when the various stages of the project are being implemented. It also included consideration of the robustness of the operation of the option to contain and isolate the waste, and/or ease of taking corrective action to ensure continued containment and isolation, in response to a wide variety of expected challenges to system integrity over the very long term. These challenges might include extreme natural events, deficiencies in option performance as designed, and an availability of any institutional controls or systems that may be required.

Comparative Assessment

Table 3-9 presents our assessment of the relative benefits and risks and uncertainty for each of the four options studied.

Table 3-9 Adaptability

	BENEFITS	RISKS & UNCERTAINTY
Option 1: Deep Geological Disposal	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. The need for adaptability in relation to financial surety is minimal. Higher initial costs and lower longer-term costs provide more financial surety. Results in the eventual permanent placement of the used nuclear fuel, which reduces or may eliminate the necessity for long-term institutional and operational continuity and financial surety. After placement and closure, provision of long-term resources and funding are not required. Is less susceptible to security breaches. This reduces the need for flexibility in relation to long-term monitoring and contingency planning. Is most robust in face of changing environmental conditions such as glaciation, climate change and societal instability. Over the long term, it is likely that institutions and governance will change. Only this 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). However, analysis indicates that the cost of retrieval from a closed Deep Geological Disposal in the Canadian Shield facility will likely be less than the incremental cost to manage the other two storage approaches over the long term.	There is some uncertainty over the performance of the system over the very long term because advance "proof" that such a system works is not scientifically possible because performance is required over thousands of years. Detailed scientific studies, models and codes, therefore, form the foundation of the assurances of performance. Science, technology, and social values may change over time, which may make a change to the management approach desirable. Such change would be very difficult to accommodate once the repository is closed. Monitoring of system performance becomes more difficult as the used nuclear fuel is placed deep underground and as the site is backfilled and closed. As well, retrieval of the used fuel for corrective action becomes much more difficult, costly, and hazardous. Flexibility to address changing conditions is low, however changing conditions are not expected to affect the performance of the system. Reversibility of decisions is difficult once facility is closed. Retrieval of the used fuel is not envisioned with this approach. Cost of retrieval is not included in the conceptual design cost estimates. Costs related to reversing adverse health or environmental effects are largely unknown. However, since it is more difficult to monitor environmental effects, after closure, it is reasonable to assume that it will take longer to discover adverse effects compared to the storage approaches that remain open for the very long term. As a result, there is greater risk and higher potential remediation cost, with this approach even though the probability of adverse effects after closure is considered to be very low.

Table 3-9 (cont'd) Adaptability

	BENEFITS	RISKS & UNCERTAINTY
Option 2: Storage at Nuclear Reactor Sites	This approach provides greater ability to monitor performance and flexibility to adapt to changing conditions. Taking corrective actions when required is easier and less costly. The waste is easier to retrieve. No transportation of used nuclear fuel would be required, as the used fuel would remain next to where it is generated. The science and technology required are well in-hand.	Requires ongoing active management and financial resources over the very long term with the associated institution controls and governance. 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. Lack of contingency plan should there be a need to remove the waste from the site. Requires 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. This is compounded by the existence of seven individual sites. The adequacy of institutions and governance in the long term is a critical consideration. The cost or liability to future generations of ensuring the financial and institutional stability of overseeing agencies will be significant.
Option 3: Centralized Storage	This approach provides greater ability to monitor performance and flexibility to adapt to changing conditions. Taking corrective actions when required is easier and less costly. The waste is easier to retrieve. The science and technology required are well in-hand.	In longer term, less able and adaptable to withstand wide variation of potential environmental and social conditions. Requires ongoing active management and financial resources over the very long term with the associated institution controls and governance. 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. Lack of contingency plan should there be a need to remove the waste from the site. 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. The cost or liability to future generations of ensuring the financial and institutional stability of overseeing agencies will be significant.

Table 3-9 (cont'd) Adaptability

	BENEFITS	RISKS & UNCERTAINTY
Option 4: Adaptive Phased Management	Offers twin benefits of developing a long term solution in a relatively short time frame, yet enables easy access and active monitoring capability up to that point. The 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 the time. This extended storage and monitoring period (out to 300 years) reduces the potential requirement for and the cost of retrieval from a "closed" long-term isolation facility. Allows for sequential decision making on whether, when and how fast used nuclear fuel is moved to final disposition. Provides a viable storage capability that can be adapted to facilitate progress and used fuel placement while providing flexibility for waste placement rates or potential retrieval. It is less dependent on institutions and governance in the long term because actions are not required after year 325 other than long-term monitoring. 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 approach sets in place an open and transparent process to continue over the long term in relation to monitoring and new knowledge about how best to deal with used nuclear fuel, and which allows for both current and near current generations to participate before it is fully implemented.	As with Option 1, there is some uncertainty over the performance of the system, once the repository is closed, over the very long term because advance "proof" that such a system works is not scientifically possible because performance is required over thousands of years. However, the extended period of technology investigation, testing and confirmation, is expected to substantially reduce this uncertainty. As with Option 2 and Option 3, it requires on-going active management and financial resources with the associated institution controls and governance. However, this is substantially less than for Option 2 and Option 3 and is expected to be limited to a period in which confidence in institutional integrity is reasonably high.

Summary Findings

Each of the four management approaches have some measure of adaptability, although the mechanisms they provide to achieve adaptability, and the degree and nature of adaptability over time, varies between the approaches.

In the near term, the storage options offer more accessibility to the waste, making it easier to monitor the waste and access the waste to take corrective action if necessary or to take advantage of new advances in waste management technologies. However, they also create long-term costs and institutional requirements that would burden future generations, and which would compete for resources with other valued objectives of the time. Should future generations not have the will or capacity (including knowledge and resources) to actively manage these facilities, the waste is vulnerable to the natural deterioration of the containment as well as a range of likely risk scenarios including climate change, human intrusion, and glaciation. Since the used fuel will be hazardous for hundreds of thousands of years, adaptability depends on the continued existence of institutions over this very long period, which is highly uncertain. Although in the short term these approaches are highly adaptable, taking into consideration both the near term and the longer term, these storage approaches are judged to perform poorly on this objective.

The deep geological disposal concept takes the hazardous material out of the accessible environment making it less vulnerable to extreme events than the other approaches. Through the combination of natural and engineered barriers, the system is designed to isolate and contain the used fuel over the long periods for which it needs to be managed without requiring institutional care or intervention.

Over the long term, the system is designed to be robust in the face of a broad range of extreme events including severe climate change, human intrusion and glaciation. However, in so doing it makes it more difficult to monitor the used nuclear fuel and to detect problems and take corrective action in the unlikely event of a breach of containment. Note that over the very long term, there is some uncertainty over the performance of the system since advance "proof" that such a system works is not scientifically possible because performance is required over thousands of years. It also makes it more difficult to take advantage of any advances in waste management technology that may become available in the future.

Over the very long term this approach is more robust in the face of extreme events, and is expected to perform better than the storage approaches. However, because this approach offers little opportunity for monitoring the performance of the system, for taking corrective action, or taking advantage of new technologies that may emerge during the period for which it is reasonable to believe that institutions and governance will remain strong, this approach is judged to be less adaptable than the Adaptive Phased Management approach.

Adaptive Phased Management offers a balance between the requirements for adaptability in the short term and in the long term. It offers the benefits of implementing an approach that in the long term does not require institutional control for effective performance, while providing for a period of easy access and active monitoring capability up to that point. It is less dependent on institutions and governance in the long term because actions are not required after Year 325 other than long term monitoring. It 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. It allows for both current and near term generations to participate in the selection and design of a long-term approach before it is fully implemented. It allows for sequential decision-making on whether, when and how fast used nuclear fuel is moved to final disposition, and it ensures there is a viable option available to reverse decisions made at each key decision point in the process. In this way it provides mechanisms to respond to changes in society, technology, economics, and the environment that will likely occur over the period of program implementation.

Summary of our Assessment Findings

As required in the *NFWA*, we have undertaken a comparison of the benefits, risks and costs of each management approach with those of the other approaches, taking into account the economic region in which that approach might be implemented, as well as ethical, social and economic considerations associated with that approach.

The framework for this comparison emerged from dialogue with citizens over the course of our study. It was designed to capture the objectives that those Canadians who participated in the study believed were important in assessing the appropriateness of any management approach for used nuclear fuel for Canada. The key objectives are: fairness; public health and safety; worker health and safety; community well-being; security; environmental integrity; economic viability; and adaptability. The comparison was also intended, as much as possible, to be responsive to the values and ethical principles which citizens suggested should drive decision-making.

We reached our conclusions through an iterative process of several stages. Our analysis suggests:

- Taken individually, no one of the management approaches specified in the *NFWA* perfectly addresses all of the objectives which citizens said it was important for any management approach for Canada to address, particularly when both the near term (the next 175 years) and the longer term is considered;
- Each of the three approaches has distinct advantages and limitations in light of this framework;
- A management approach which incorporates the most significant advantages of each approach, supported by a phased decision-making process designed to actively and collaboratively manage risk and uncertainties, is expected to perform better on our objectives than the other three approaches; and
- The process of implementation will be a test of the degree to which any of the approaches would ultimately address citizen objectives, values and ethical principles. Therefore, the requirements for an implementations plan form an essential part of our recommendation.

The storage options, Option 2 – Storage at Nuclear Reactor Sites and Option 3 – Centralized Storage, are expected to perform well over the near term (at least within the next 175 years). However, the existing sites were not chosen for their technical suitability as permanent storage sites. Furthermore, the communities hosting the nuclear reactors have an expectation that the used nuclear fuel will eventually be moved.

The NWMO believes that the risks and uncertainties concerning the performance of these storage approaches over the very long term are substantial in the areas of public health and safety, environmental integrity, security, economic viability and fairness. A key contributing factor in this expected performance is the extent to which the storage approaches rely upon strong institutions and active management to ensure the safe and effective performance of the management system. The NWMO expects that these institutions and capacity for active management will be strong over the foreseeable future, but uncertain over the very long term. The NWMO believes that the type of responsible and prudent approach that Canadians have suggested is required dictates that we not rely upon the existence of strong institutions and active management capacity over thousands and tens of thousands of years. On this basis, the NWMO does not suggest either of the storage options as a preferred approach for the long term.

Deep Geological Disposal in the Canadian Shield, Option 1, is judged to perform well against the objectives in the very long term because of the combination of engineered and natural barriers to isolate the used fuel. A key weakness, however, is its lack of adaptability, which is an important objective in the minds of citizens. Over the short term, the approach is judged to be less flexible in responding to changing knowledge or circumstances either concerning the performance of the system itself over time, or more broadly to innovations in waste management technologies. There is some uncertainty about how the system will perform over the very long term because we cannot obtain advance proof of the actual performance of the system over thousands of years. Also, this approach provides comparatively little opportunity for future generations to influence the way in which the used fuel is managed. Its lack of adaptability is a weakness that may ultimately affect the performance of the system over time on the other objectives such as public health and safety and environmental integrity.

Adaptive Phased Management, Option 4, has been designed to build upon the advantages of each of the three approaches studied and includes as an important element an adaptive and phased approach to implementation which is designed to reduce the uncertainties at each phase in the process and over time. Involvement of citizens in decision-making throughout all of the phases is important. The NWMO considers Option 4 to offer a preferred approach.

- This approach is designed to be highly adaptive in the near term, the period in which it is reasonable to believe there will be strong oversight institutions and active management capacity. It entrenches an explicit and planned process of social learning and action. Over this period, new learning and technological innovation is easily incorporated into the management plan. Some social uncertainties, such as the role of nuclear generation in the energy mix in Canada's near future, may be resolved. Some technical uncertainties, such as whether evolving technologies (i.e., transmutation) will become practicable, are also likely to be reduced. Some uncertainties over the performance of aspects of the deep geological system are also expected to be reduced with further research, testing and experimentation, particularly at the location where such a facility might be sited;

- This approach also clearly identifies the technology associated with a deep geologic repository as the appropriate end point. It does not rely upon human institutions and active management for its safe performance over the long term. The approach plans for and puts in place a safe and secure containment option for the used nuclear fuel at each point in the process. It provides real options and contingency plans should implementation through the phases not proceed as planned. In particular it provides the option of more robust and secure interim storage in shallow underground caverns located centrally at the site of the deep repository;

- The approach provides opportunity for future generations (at least over the next 300 years) to influence the way in which the fuel is managed;

- The approach provides for research and collaborative decision-making in the determination of the manner and timing of movement through the phases; and

- The approach suggests a process through which confidence in the technology and supporting systems can be developed before moving to the final phase.

Finally, our analysis suggests that some important issues are not fully addressed through the selection of the management approach itself. They will need to be considered through the collaborative decision-making process, which should accompany the implementation of any approach. These issues include the design of a fair siting process and the determination of safety thresholds that would need to be met before moving to the next phase of implementation.

PART FOUR Response to Legislated Study Requirements

ANALYSIS

The *Nuclear Fuel Waste Act* (*NFWA*) (*An Act respecting the long-term management of nuclear fuel waste*) was brought into force by the Canadian Parliament in November 2002. The purpose of the *NFWA* is to provide a framework to enable the Government of Canada 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 *NFWA* provides explicit direction on parameters that must be included in the NWMO study of management approaches that is to be submitted to the Minister of Natural Resources Canada.

Throughout Part Four, we seek to make transparent our interpretation of the study requirements and how we discharged our obligations in addressing each relevant section of the *NFWA*.

In Chapters 5 through 10, we report on our response to each of these legislated requirements relating to the analysis of management approaches.

The *NFWA* is accessible through our website at www.nwmo.ca/nuclearfuelwasteact.

CHAPTER 5 / THE NWMO STUDY

Nuclear Fuel Waste Act (*NFWA*) reference:
12. (1) Within three years after the coming into force of this Act, the waste management organization shall submit to the Minister a study setting out

(a) its proposed approaches for the management of nuclear fuel waste, along with the comments of the Advisory Council on those approaches; and

(b) its recommendation as to which of its proposed approaches should be adopted.

Section 12(1) of the *NFWA* addresses the principal purpose of our study.

Our Study Focus

The focus of our study, as mandated by the *NFWA*, is the long-term management of nuclear fuel waste, defined as irradiated fuel bundles removed from a commercial or research fission reactor.

Consistent with the three-year study timeline provided under the *NFWA*, we will be submitting our final study to the Minister of Natural Resources Canada by November 15, 2005.

In the chapters that follow, we set out:

a) The management approaches we studied; and
b) Our draft recommendation on a management approach.

The final study, when submitted in November 2005, will report on the full set of approaches studied by the NWMO, including the Advisory Council comments on those approaches.

Our Interpretation of "Management Approach"

In determining how we would articulate "management approaches" for consideration in our study, we were guided by the *NFWA* which defines "management" of nuclear fuel waste as the "long-term management by means of storage or disposal, including handling, treatment, conditioning or transport for purpose of storage or disposal." Our concept of management approach also builds upon the components of implementation plans, required under Section 12 of the *NFWA*.

We also drew upon our discussions with Canadians.

What has become clear to us through our study and engagement with the general public and with Aboriginal Peoples, is that any management approach set out in the study must embody much more than simply a technical method for containing used fuel and its engineering design. Approaches must fully consider ethical, social, cultural, environmental and economic dimensions, and they must be sensitive to the impacts that any approach may have on Canadians' way of life and their aspirations. During the course of our discussions with Aboriginal Peoples, we have learned that Traditional Aboriginal Wisdom and Knowledge apply to a similar span of substantive and process-related insight. Management approaches must be considered not just for their technical design attributes, but also the way in which they are implemented, the way in which decisions are taken, the provisions for review and the scope for ongoing societal involvement. It is through a fully developed management plan that we seek to earn the confidence of Canadians.

Consistent with the *NFWA*, and building upon discussions with Canadians, we interpret the concept of a management approach to consist of both a technical method and a management system. The technical method involves a type of technology, such as continued on-site storage or a deep geological repository, along with its detailed design and transportation systems. The management system includes the institutions, governance, financial arrangements, and managerial and legal frameworks designed to oversee and guide the implementation and operation of the technical method through the various phases of its operating life. We will weave together all of these elements in a comprehensive implementation strategy.

CHAPTER 6 / ENGAGEMENT

Nuclear Fuel Waste Act (*NFWA*) reference:
12. (7) The waste management organization shall consult the general public, and in particular aboriginal peoples, on each of the proposed approaches. The study must include a summary of the comments received by the waste management organization as a result of those consultations.

Public engagement represents an important cornerstone of our legislated mandate under the *Nuclear Fuel Waste Act* (*NFWA*). We solicited comments on the management approaches under review as part of our study through a broad dialogue with the public at large, Aboriginal Peoples, experts, and other communities of interest.

We adopted a reflective study approach that enabled us to share preliminary work as the basis for public discussion and input as we sought to understand citizens' views on the management options. Building on the public's comments, we continued to enrich our assessment methodologies as we compared the benefits, risks and costs of the different management approaches. We focused our public dialogue around the three management methods specified in the *NFWA*, to learn how Canadians viewed the relative strengths and limitations of each approach. Through this, we were guided in our development of a fourth management approach. As we discussed the different management approaches with Canadians, we also invited discussion around implementation, and the priorities identified as essential components for moving forward with any of the management approaches. We asked if there were specific elements that people felt must be built into an implementation plan, and we asked about their thoughts on what a phased approach must include. Implementation considerations have emerged as key elements of a management approach for many with whom we met, and many comments were offered in this regard.

At a much broader level, comments from Canadians have been instrumental in guiding our processes and the way in which we assessed the options and developed our recommendations. For example, we invited guidance from Canadians on how we should structure our work plan, our public reports and public engagement programs, to best meet their expectations for our study. We invited input from Canadians through broad consultation, so that our work would reflect the values and perspectives of society. We then asked citizens to help shape the questions to be asked in the analysis and to offer comment on how those questions should get answered in the course of the study as we examined each option. We approached our study in its entirety as an iterative process of learning and response, allowing for adjustments along the way in response to expectations and needs of Canadians. We are indebted to the many thousands of Canadians who through their participation have provided guidance in the course of our study.

In Part Two, we described how we designed our programs to engage the general public, nuclear site communities and many individuals and organizations with an interest in this issue. Our engagement with Canada's Aboriginal Peoples remains a key element of our program. We have sought to use the existing capacity-building arrangements between Aboriginal organizations and the federal government, and to enrich them. Our dialogues with Aboriginal Peoples are designed and delivered by Aboriginal People and organizations, with support as needed from our human, financial and technical resources. In coordination with the national programs under way, we also welcome the expertise from local or regional Aboriginal organizations.

The summary of comments received through these public engagement processes is reported in Part Two of this document. We report on comments received on each of the three management approaches that had been the focus of our public engagement to date, and on the broader issues concerning implementation that have arisen in our work.

Detailed reports on comments from individual dialogues are available on our website.

CHAPTER 7 / METHODS CONSIDERED IN OUR STUDY

Nuclear Fuel Waste Act (*NFWA*) reference:
12. (2) Each of the following methods must be the sole basis of at least one approach:

(a) deep geological disposal in the Canadian Shield, based on the concept described by Atomic Energy of Canada Limited in the *Environmental Impact Statement on the Concept for Disposal of Canada's Nuclear Fuel Waste* and taking into account the views of the environmental assessment panel set out in the *Report of the Nuclear Fuel Waste Management and Disposal Concept Environmental Assessment Panel* dated February 1998;

(b) storage at nuclear reactor sites; and

(c) centralized storage, either above or below ground.

Section 12(2) of the *Nuclear Fuel Waste Act* (*NFWA*) specifies three technical methods to be the basis of approaches considered in our study. The *NFWA* also allows us to consider other management approaches.

7.1 / Our Initial Screening of the Options

For about four decades, various countries have been investigating many possible methods to manage used nuclear fuel and other long-lived highly radioactive wastes over the long term.

Accordingly, in our first discussion document, *Asking the Right Questions*, we began by reviewing 14 different options that have been considered internationally in recent years. We categorized them in three ways:

- Methods requiring review as specified by the *NFWA*;
- Methods receiving international attention; and
- Methods of limited interest.

These options were subject to review both by our Assessment Team, and by Canadians who offered views and perspectives through technical workshops, formal comments and discussion in public dialogues. In the sections below we highlight our general findings concerning these three categories of methods for managing used nuclear fuel.

Methods Requiring Review

The *NFWA* requires that we study, at a minimum, management approaches based on the following individual technical methods:

- Deep geological disposal in the Canadian Shield;
- Storage at nuclear reactor sites; and
- Centralized storage, either above or below ground.

While it is not intended to dismiss future options and possibilities, it is clear that the three long-term management methods specified in the *NFWA* are of immediate interest to Canada. These three methods are also being assessed in detail and, in some cases, being implemented in other national radioactive waste management programs around the world.

Methods Receiving International Attention

We looked at the following methods currently receiving international attention. These include:

- Reprocessing, partitioning and transmutation;
- Placement in deep boreholes; and
- The international used nuclear fuel repository concept.

These options were screened out of our comparative assessment for the reasons outlined below. Our Assessment Team noted, however, that Canada may wish to maintain some interest in each of these options by undertaking research and/or tracking related international developments.

Reprocessing, Partitioning and Transmutation

Reprocessing and the current status of partitioning and transmutation technologies were considered in our study in light of the ongoing international work to understand the potential of these processes for managing used nuclear fuel in the long term. Our research into these areas throughout our study was further motivated by the high level of interest registered by Canadians in knowing more about the potential to "recycle" or "reuse" used fuel, options we have come to expect in many other areas of our life. Interested in opportunities to "recycle" in the context of used nuclear fuel, and intrigued by international work on transmutation as a potential for reducing the long-term hazard of used nuclear fuel, Canadians expressed a desire for us to report back on our findings and determinations concerning these options.

Reprocessing is the application of chemical and physical processes to used nuclear fuel for the purpose of recovery and recycling of fissionable isotopes. Partitioning involves a series of physical and chemical separation processes. Transmutation involves the conversion of one element into another by means of particle bombardment.

For a number of reasons, reprocessing as a management approach for used nuclear fuel is considered to be highly unlikely as a viable option for Canada at this time. The necessary facilities are very expensive and inevitably produce residual radioactive wastes that are more difficult to manage than used nuclear fuel in its un-reprocessed form. Reprocessing also requires a commitment to an expanded and multi-generational nuclear fuel cycle, and it potentially separates out weapons-grade material (plutonium) in the course of the process. The abundant reserves of natural uranium in Canada suggest that it is unlikely that Canada will implement reprocessing in the near future. Canada is a leader in uranium mining and Canadian uranium reserves are far from being depleted. The cost of reprocessing is quite high and is not about to be exceeded in the near future by the cost of mined natural uranium.

If in the future there were a decision to further process CANDU fuel for the purpose of reducing the volume of high-level radioactive waste and toxicity of the fuel, there would need to be significant advances in the area of partitioning and transmutation.

As opposed to reprocessing, which is routinely carried out on a commercial scale, partitioning and transmutation is still in its early developmental stage. Introduction of partitioning and transmutation on a commercial scale would require an additional process step at the back-end of the nuclear fuel cycle and a commitment to the continued use of nuclear energy by current and future generations. While partitioning and transmutation might reduce the volume and the toxicity of the used nuclear fuel to be managed, it would not avoid the requirement for long-term management of the residual high-level radioactive wastes that would be produced.

Partitioning and transmutation continues to be the subject of considerable study internationally, in particular in France, where substantial funds have been devoted over the past several years to examining the feasibility of partitioning and transmutation as a complementary option for managing used fuel in the future. Based on this research, the scientific and technical foundation is not yet sufficiently advanced for implementation and long-term management of the residual materials would still be required. In a recent report from France, the Autorité de sûreté nucléaire française (French Nuclear Safety Commission) reported, "industrial implementation of transmutation cannot be foreseen until the years 2040-2050 at best."

The possibility of transmuting various radioactive elements has only been demonstrated in the laboratory. It is too soon to demonstrate that it would be commercially feasible with the volume of used nuclear fuel that exists in Canada. We recommend keeping a "watching brief" on the findings concerning partitioning and transmutation. Systematic monitoring of this technology and other areas of evolving scientific research will continue to be an important function of the NWMO, to stay abreast of current developments concerning the long-term management of used nuclear fuel.

For a fuller discussion on this topic, see Appendix 8, and NWMO background papers on reprocessing, partitioning and transmutation, available at www.nwmo.ca/partitioningandtransmutation and www.nwmo.ca/implicationsrpt.

Placement in Deep Boreholes

Deep borehole placement of radioactive waste has been examined in a number of countries, including Sweden, Finland and Russia. The application of this concept as a used nuclear fuel management option would involve placing used fuel packages in very deep boreholes drilled from the surface to depths of several kilometres, with borehole diameters typically less than one metre. The packages would be stacked on top of one another in each borehole, separated by layers of sealing material such as bentonite or cement. Boreholes could be drilled in many types of rock; however, monitoring and retrieval of the used nuclear fuel packages would be very difficult. Furthermore, a number of significant technical questions remain regarding the mechanical integrity of the used fuel packages under high stress and temperature conditions both during and after emplacement, thus necessitating significant further research and development. Deep borehole placement is currently viewed as a possible method for the disposal of small quantities of radioactive waste but would be difficult to implement as a management option for large quantities of used nuclear fuel.

International Repository Concept

We looked at the concept of an international repository, both in the case where the repository would be located in another country and where Canada would be the host. It was noted that the assessment of an international repository option would have to include all the attendant costs, benefits, and risks of the particular site and related infrastructure (including transportation) and this would be linked to all of the implicated societies and cultures. It was also noted that while the transboundary movement of used fuel would not be against any international treaty, in some cases it might violate the self-sufficiency principle which guides the radioactive waste management activities of most countries with substantial nuclear reactor programs (those who produce the used fuel will assume full responsibility for its long-term management). It was acknowledged that the international repository option might become more attractive for some countries over the next few years, but it is not a decision that would be made solely by Canada. In the meantime, we can keep abreast of developments in this area by coordinating with other countries and international agencies that are examining this option.

Methods of Limited Interest

We found eight of the methods as being of limited interest. We screened these eight methods out as potential options based on the following criteria:

- Contravention of international treaties (e.g., the Convention on the prevention of marine pollution by dumping of wastes and other matter); and/or

- Insufficient proof-of-concept to undertake an adequate assessment at the conceptual design level.

Further rationale for screening these methods out of the assessment is provided in Appendix 9.

We note that this judgement is consistent with assessments undertaken in other countries. We recognize, however, that Canada may wish to maintain interest in some of these methods by undertaking research and/or tracking related international developments.

7.2 / Methods Considered in Our Study

From our initial review of 14 options, we narrowed the options to four, which subsequently became the focus of our study.

As required by the *NFWA*, we studied individual approaches based on each of the three technical methods specified for study under the *NFWA*:

Option 1: Deep geological disposal in the Canadian Shield;

Option 2: Storage at nuclear reactor sites; and

Option 3: Centralized storage, either above or below ground

In addition, we have studied a fourth option.

Option 4: Adaptive Phased Management, which combines many features of the three technical methods listed in the *NFWA*.

Details of each approach studied are presented in Chapter 8.

The findings of the comparative assessment of the four options are summarized in Part Three.

Table 4-1 Screening Options for Review

14 OPTIONS INITIALLY SELECTED FOR REVIEW
Methods Requiring Review
Deep Geological Disposal in the Canadian Shield (modified AECL concept)
Storage at Nuclear Reactor Sites
Centralized Storage, Above or Below Ground
Methods Receiving International Attention
Reprocessing, Partitioning and Transmutation
Placement in Deep Boreholes
International Repository Concept
Methods of Limited Interest
Dilution and Dispersion
Disposal at Sea
Disposal in Ice Sheets
Disposal in Space
Rock Melting
Disposal in Subduction Zones
Direct Injection
Sub-Seabed Disposal

4 OPTIONS SELECTED FOR STUDY
Deep Geological Disposal in the Canadian Shield (modified AECL concept)
Storage at Nuclear Reactor Sites
Centralized Storage, Above or Below Ground
Adaptive Phased Management

CHAPTER 8 / TECHNICAL DESCRIPTIONS OF APPROACHES

Nuclear Fuel Waste Act (*NFWA*) reference:
12. (3) The study must include a detailed technical description of each proposed approach and must specify an economic region for its implementation.

The *Nuclear Fuel Waste Act* (*NFWA*) addresses the description required for the approaches studied by the NWMO.

8.1 / The Development of Technical Designs

The three methods outlined in the *NFWA* are well understood and are considered to be technically credible and viable. Used fuel storage technologies have been demonstrated for many years at reactor sites where used fuel is cooled and then safely stored in interim storage facilities. Deep geological disposal has been the subject of intensive study in Canada over a period spanning many decades, and is in an advanced state of scientific and technical understanding internationally.

In 1978, the governments of Canada and Ontario established the Canadian Nuclear Fuel Waste Management Program to study and advance the technology for storage, transportation and permanent disposal of Canada's nuclear fuel waste. Since that time, the research and development program has been directed at developing and demonstrating methods for interim storage of used fuel at Canada's nuclear facilities in Ontario, Manitoba, Québec and New Brunswick, and developing the technology for deep geologic disposal in the crystalline rock of the Canadian Shield. Although crystalline rock was the primary focus of the disposal research and development program in Canada, it was recognized in the 1977 study by Kenneth Hare, that there are other potentially suitable rock types, such as sedimentary rock and salt, for a deep repository based on studies and experience in other countries.

Over the past several decades, all of the waste owners (Ontario Power Generation Inc., Hydro Québec, NB Power Nuclear and Atomic Energy of Canada Limited), have designed, developed and implemented licensed interim used fuel storage technology at the reactor sites in Canada. For example, there are operating dry storage facilities at the Pickering and Bruce Power Nuclear Generating Stations and a licence to construct a dry storage facility at Darlington was issued by the Canadian Nuclear Safety Commission on August 11, 2004. While these facilities have been designed for interim storage for approximately 50 years, conceptual designs for long-term storage have been developed and submitted to us. (See conceptual design reports at www.nwmo.ca/conceptualdesigns). The waste owners are also conducting studies into the integrity of used fuel under storage conditions over hundreds of years.

Conceptual designs have also been developed for the transportation of used nuclear fuel. The status of transportation systems for used nuclear fuel in Canada and abroad has been summarized in background papers on our website.

Since 1978, Canada has spent over $800 million on used fuel technology development. Ontario Power Generation Inc., on behalf of the nuclear fuel waste owners, has been ensuring that Canada has the capability to implement a deep geologic repository program, should the federal government choose this technology. Since 1996, OPG has been managing the technology development program in Canada and addressing the technical issues raised during the federal review of AECL's 1994 disposal concept. These issues were reported on by the Seaborn Panel in 1998 and were derived primarily from the findings of their Scientific Review Group (1995) and others during the federal hearings. Progress on these technical issues has been documented in a series of annual reports from Ontario Power Generation Inc. since 1997. Key technical and design changes to the Canadian concept include a more robust long-lived used fuel container capable of withstanding the effects of glaciation, and design improvements for monitoring and retrieval of used fuel in a deep geologic repository. (See repository technology development reports at www.nwmo.ca/repositorytechnology).

In 2004, Ontario Power Generation Inc.'s Deep Geologic Repository Technology Program had a budget of $7.6 million per year. The main objectives of the research and development program were to further develop safety assessment, geoscience and engineering methods, models and tools required to assess the feasibility and safety of the deep geologic repository concept. It is maintaining sufficient technical expertise to initiate a siting program, pending a decision by the federal government. Research and development is being conducted by technical experts at AECL and Canadian universities, as well as by the consulting community in Canada and abroad. Over 30 technical reports and publications are produced each year in research areas such as:

- Used fuel container development;
- Copper corrosion modeling and experimental studies;
- Sealing material properties and behaviour under repository conditions;
- Rock mass characterization and monitoring instruments and methods;
- Repository design development (e.g., in-floor, in-room, long-tunnel emplacement);
- Modeling regional groundwater flow and transport in Canadian Shield;
- Long-term climate change, glaciation modeling and permafrost studies;
- In-situ transport studies and geosphere model development;
- Used fuel dissolution studies and vault model development;
- Postclosure safety assessment studies and safety model development; and
- Canadian contribution to international waste management studies and analyses.

These research and development activities are designed to improve the understanding of the expected evolution of a deep geologic repository over very long periods of time (around one million years) and to provide confidence in the safety case for emplacing used nuclear fuel in a deep geologic repository.

Formal co-operation and information sharing agreements are in place between Ontario Power Generation Inc. and radioactive waste management organizations in Sweden (SKB), Finland (Posiva) and Switzerland (Nagra). These countries are considering used fuel repository concepts and geo-media (rock formations) that are similar to the Canadian repository concept, and several of these programs are advanced with respect to repository siting and approvals. Finland and Sweden plan to have repositories in service by 2020. In the event that the federal government selects an approach with a deep geologic repository, these countries are about 15 to 20 years ahead of a Canadian facility. Thus, Canada can learn from the siting and repository development experiences in other countries. Appendix 10 provides an overview of activities in other jurisdictions.

Representatives from Canada participate in the international radioactive waste management program of the OECD Nuclear Energy Agency. Members of this group include all the major nuclear energy countries, both waste owners and national regulators. In December 2003, Ontario Power Generation Inc. signed a five-year agreement with SKB to participate in important research and repository technology demonstration activities at the Äspö Hard Rock Laboratory (HRL) in Sweden. Canadian participation in international co-operation projects such as Äspö enhances the technology base in Canada and helps improve our understanding of key processes in a deep repository.

Ontario Power Generation Inc. plans to maintain the Canadian repository development program until a federal government decision is made on long-term management of used fuel, expected in 2006.

Internationally, many decades of research into the science and engineering aspects of storage and repositories over many decades have advanced our understanding of these different technical methods. Today, storage and repositories both represent viable, safe options for the management of used nuclear fuel.

8.2 / Engineering Concepts for the NWMO Study

The technical engineering designs underlying the concepts assessed by us are based on decades of study on geologic repositories, and first hand experience with design and use of different storage options. The conceptual engineering designs that we adopted for our study is work commissioned by the Joint Waste Owners: Ontario Power Generation Inc., Hydro-Québec, NB Power Nuclear and Atomic Energy of Canada Limited.

Drawing on the understanding of years of investigation into used fuel management methods, the waste owners commissioned engineering consulting firms to develop preliminary conceptual engineering designs for the three technical methods identified in the *NFWA*, and also to develop associated used fuel transportation infrastructure and cost estimates for those designs. This information was developed to be typical technical options, and was not intended to be fully developed project plans or recommendations. The potential engineering designs for deep geological disposal, reactor site storage and centralized storage are available at www.nwmo.ca/conceptualdesigns. Preliminary cost estimates for siting, construction, operation, monitoring, closure and decommissioning each of the three conceptual designs are available from us. Cost summary reports are available at www.nwmo.ca/costsummaries. The preliminary design of the types of facilities and infrastructure needed to support transportation of used fuel to centralized facilities is available at www.nwmo.ca/conceptualdesigns.

This work was based on the assumption that the current fleet of commercial nuclear reactors in Canada would continue to operate for an average lifetime of 40 years. Under this assumption, the used fuel inventory would be approximately 3.6 million used fuel bundles for conceptual design and cost estimating purposes. Sensitivity analyses were also conducted for average reactor lifetimes of 30 years and 50 years.

We commissioned a third-party review of this body of work to examine the appropriateness of key engineering design assumptions and the cost estimation process. (www.nwmo.ca/engineeringreview) The third party review of the cost estimates concluded that the cost estimates have been prepared with an appropriate estimating methodology and are suitable for the options review and directional decision-making requirements of the NWMO. (www.nwmo.ca/costreview)

Under the *NFWA* we also had the possibility of considering and presenting another approach for the long-term management of Canada's used nuclear fuel.

Following significant analytical work and contributions from our public engagement programs, we identified an additional option for study. We present Option 4: Adaptive Phased Management (our recommended approach) as an adaptive risk management approach that draws on many of the features of the other three options, and which we believe will ensure a high degree of safety and security for the long term, while providing the flexibility and adaptability that is essential for a very long-term project.

We prepared the initial high-level description of Option 4 based on the conceptual engineering designs for storage at nuclear reactor sites, centralized storage and a deep geologic repository. The description of Option 4 was submitted to engineering consulting firms to review the technical feasibility of the concept and to develop a preliminary cost estimate for the approach. These reports are available at www.nwmo.ca/assessments.

For each of the four methods that we studied, we summarize the distinguishing features in the following tables.

> References to implementation timelines in the sections below should be considered as possible timelines, assumed in the conceptual designs for cost estimation purposes only. These illustrative timelines should not be considered as the definitive implementation timetables, which would need to be developed following a decision on the preferred management approach by the federal government.

The detailed technical descriptions for the reference used fuel inventory are available in full for review at www.nwmo.ca/conceptualdesigns.

Option 1: Deep Geological Disposal in the Canadian Shield

Option 1: Deep Geological Disposal in the Canadian Shield

The management approach:

- Long-term management of used nuclear fuel through containment and isolation in a deep geologic repository in the crystalline rock of the Canadian Shield;
- Used nuclear fuel is transported from the nuclear reactor sites to a central location for long-term management;
- The deep geologic repository is based on the concept described by Atomic Energy of Canada Limited in the Environmental Impact Statement on the Concept for Disposal of Canada's Nuclear Fuel Waste, and modified to take into account the views of the environmental assessment panel as reported in February 1998; and
- Following an interim period of monitoring, the repository is closed, without the intent to retrieve the used fuel.

A deep geological repository relies on natural and engineered barriers to isolate the used fuel from the surface environment over its hazardous lifetime. Within the disposal concept, a repository is a facility deep underground where used fuel is placed for final containment and isolation.

During the period 1978 to 1996, Atomic Energy of Canada Limited (AECL) researched the idea of a deep geologic repository for used CANDU fuel, under the Canadian Nuclear Fuel Waste Management Program. Subsequently, the Seaborn Panel reviewed that concept under the *Federal Environmental Assessment and Review Process Guidelines Order (1984)*. The Panel listened to a broad range of stakeholders, including members of the public. In its final 1998 report, the Panel recommended changes to address their comments. Since then, the Joint Waste Owners have continued researching and advancing the original AECL repository concept.

The approach described here is based on the concept initially developed by AECL, and further developed taking into account recommendations of the federal environmental assessment that was completed in 1998, as well as further repository design experience in Canada and internationally. The main changes to the AECL concept include monitoring of used nuclear fuel after placement in the deep repository and the technology to retrieve the used fuel from the facility.

The illustrative timelines and activities associated with the concept are summarized in Table 4-2.

The detailed technical description of the conceptual designs used in our assessment is provided at: www.nwmo.ca/geologicaldisposal.

Figure 4-1 Deep Geological Disposal in the Canadian Shield

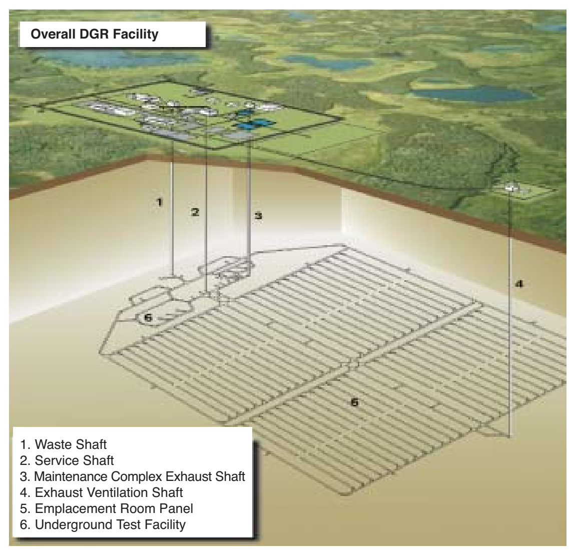


Table 4-2 Option 1: Deep Geological Disposal in the Canadian Shield (modified AECL concept)

Representative Conceptual Design	
Concept	A long-term management approach based on a deep geologic repository located on the Canadian Shield at a nominal depth of 500 to 1,000 metres below surface. Fuel would be transported from existing interim storage facilities at nuclear reactor sites, and moved to a central location. At the central facility, the used fuel would be transferred into corrosion-resistant containers that would be placed in rooms excavated deep in the rock over a period of about 30 years. There would be a need for transportation containers and facilities to produce them; processing facilities to load the fuel into transportation containers; production facilities for deep repository containers; processing facilities to transfer the fuel from transportation to deep repository containers; and production facilities for sealing materials. Once all of the used fuel is transferred to the repository, it would be monitored over time prior to final backfilling and sealing the facility. Following closure of the deep repository, maintenance, inspection and security-related operations would be minimal. Such a facility would be designed to be passively safe over the long term and not rely on institutional controls to ensure safety.
Location	The facility would be located in the crystalline rock of the Canadian Shield, a vast rock formation stretching across parts of six provinces and two territories. A specific location would need to be identified and licences would be required from the Canadian Nuclear Safety Commission for the construction and operation of the facility. This would also involve an environmental assessment.
Transportation Requirements	The operation of the centralized facility would involve moving the fuel from existing reactor site storage facilities in certified transport containers to the central site over a period of approximately 30 years. Transportation will require an emergency response plan and adherence to security provisions. The mode of transportation (road, rail or water) would depend upon factors such as the location of the central facility.
Containers	At the central facility, used nuclear fuel would be placed in durable corrosion-resistant containers. This type of container can be designed to last a minimum of 100,000 years, and is capable of withstanding the hydraulic pressures of glaciations. Facilities will exist at the central site for repackaging the used fuel.
Underground Facility	A network of horizontal tunnels and rooms would be excavated in stable rock about 500 to 1,000 metres below the surface. Used nuclear fuel would be packaged in durable containers and placed within the rooms or in boreholes drilled into the floor of the rooms. Used fuel containers are assumed to be placed in a deep repository over a 30-year operating period.

Table 4-2 (cont'd) Option 1: Deep Geological Disposal in the Canadian Shield

Representative Conceptual Design	
Repository Sealing System	Clay-based materials would be used to surround and protect the containers, to fill the void spaces in the repository, to limit the movement of groundwater and dissolved material, and to protect workers during container placement operations. These are referred to as sealing systems, and involve materials such as high-performance concrete and swelling bentonite clay.
Geosphere Barrier	The geosphere, or host rock, provides the principal barrier between the used fuel containers and the surface environment. The crystalline rock of the Canadian Shield is a naturally-occurring geologic formation which has long-term stability, good rock strength, low groundwater flow, and is sufficiently below the surface and lacking in mineral resources that it is very unlikely to be disturbed by erosion or accidental drilling.
Monitoring	The facility would be monitored for an extended period of time to confirm the performance and safety of the system prior to final sealing, decommissioning and closure of the repository. Extended monitoring of the used fuel containers, sealing systems, rock around the repository, underground water flows and the natural environment would be conducted to confirm the long-term safety and performance of the system. In addition, some preventive maintenance might be required. For costing purposes it was assumed that extended monitoring at repository depth would occur over approximately 70 years, although it could be shorter or longer.
Implementation Schedule	A government decision in 2006 to develop a deep geological repository would see the new facility ready in 2035, at the earliest. Following a decision by the government, the major phases for implementing a deep geologic repository include: • Siting (which would take about 15 years); • Design and construction (about 15 years); • Operation (about 30 years to emplace the fuel plus 70 years of additional monitoring); • Decommissioning (about 12 years); and • Closure (about 13 years). There will be a need to obtain a licence at each phase and demonstrate continuous compliance with the licence (under regulatory oversight).
Decommissioning	Once necessary approvals were obtained, decommissioning would commence and all underground access tunnels and shafts would be backfilled and sealed. Surface facilities would be decontaminated and dismantled. Closure activities include removal and sealing of monitoring instruments and returning the site to greenfield conditions. There is the option of continued postclosure monitoring, should society at the time require this provision.
Costs	The cost of a deep geologic repository for used nuclear fuel is estimated to be $16.2 billion (2002 dollars), including interim used fuel storage and retrieval from reactor sites, and transportation costs to the central facility. These costs include the development and demonstration of the technology to retrieve used fuel from the repository, but not the costs of performing the retrieval operations. The present value cost based on current long-term economic factors is approximately $6.2 billion (2004 dollars). (www.nwmo.ca/disposalcosts)

Option 2: Storage at Nuclear Reactor Sites

Option 2: Storage at Nuclear Reactor Sites

The management approach:

- Long-term management of used nuclear fuel in storage facilities, at or just below surface, at each nuclear reactor site in Canada; and
- Storage facilities are maintained, rebuilt and operated in perpetuity at each reactor site.

The illustrative timelines and activities associated with the concept are summarized in Table 4-3.

The detailed technical descriptions, presented for the conceptual designs, are provided at: www.nwmo.ca/reactorstorage.

Figure 4-2 Example of Used Fuel Storage in Bays at Reactor Site

Figure 4-3 & 4-4 Example of Used Fuel Storage in Dry Storage at Reactor Sites – Surface Storage Building and Dry Storage Containers

Table 4-3 **Option 2: Storage at Nuclear Reactor Sites**

Representative Conceptual Design	
Concept	Long-term storage at existing reactor sites would involve the expansion of existing dry storage facilities or the establishment of new, long-term dry storage facilities at each of the seven used fuel storage sites in Canada. In the latter case, used fuel would be transferred from the existing interim storage facilities to newly designed storage containers and storage. Storage would require an ongoing program of regular replacement and refurbishing activities, as facilities would be renewed indefinitely. Processing buildings would also be required to load the fuel and provide for its on-site transfer. The storage facilities would require ongoing maintenance, inspections and security systems.
Location	Long-term storage would need to be established at the seven licensed Canadian reactor sites: • Whiteshell Laboratories, Manitoba • Bruce Nuclear Power Station, Ontario • Pickering Nuclear Power Station, Ontario • Darlington Nuclear Power Station, Ontario • Chalk River Laboratories, Ontario • Gentilly Nuclear Power Station, Québec • Point Lepreau Nuclear Power Station, New Brunswick This would involve identifying specific storage locations at each reactor site, and obtaining the necessary licenses from the CNSC for the construction and operation of the facilities, and potential environmental assessments.
Transportation Requirements	No off-site transportation of used fuel is required for extended storage at nuclear reactor sites.
Containers	There are both surface and below-surface design options for reactor site storage, involving the use of casks, vaults and/or silos. The alternative conceptual designs considered reflect the different methods currently used for interim storage at each location in Canada.
Underground Facility	One of the possible reactor site concepts involves storage slightly below ground, in shallow trenches.
Repository Sealing System	None. There would not be a deep repository to be sealed.

Table 4-3 (cont'd) Option 2: Storage at Nuclear Reactor Sites

Representative Conceptual Design	
Storage Design Life	Eventually the storage containers and buildings would need to be replaced. This would involve construction of new storage buildings, transfer of the used fuel from the long-term storage containers to new packages, and transfer of the containers to the new buildings. The old buildings and waste storage containers would need to be refurbished or demolished. These activities would take approximately 30 years, and repackaging of the fuel is assumed to be repeated every 100 years. Based on current design assumptions, complete refurbishment of all components of the storage facilities would be required every 300 years. For design purposes, the assumed service lives for the various storage facility components are: • Casks 100 years • Fuel module 300 years • Fuel basket 300 years • Trench chamber 200 years • Storage building 100 years • Processing building 50 years It is recognized that new designs may make possible extended service lives of the facilities.
Monitoring	Once all the used fuel from the reactor site was placed in the long-term storage facility, it would require ongoing monitoring to ensure that the facility was being safely maintained, and to ensure preventive maintenance and repair.
Retrieval	Storage would be designed to allow the safe retrieval of used fuel at any point during the life of the facility.
Geosphere Barrier	None. Maintained either above ground, or slightly below the surface. Geosphere would not provide a significant long-term isolation barrier.
Implementation Schedule	A government decision in 2006 to adopt storage at nuclear reactor sites, followed by immediate implementation would mean sites would be ready between 2016 and 2020. (The range reflects the different design options at the various reactor sites.) The long-term storage facilities would likely require complete refurbishment or replacement by the year 2300. A decision to implement long-term storage at reactor sites could lead to the development of new long-term storage facilities at each of the reactor sites in Canada. While the long-term storage facility may vary at each reactor site, the major phases and their typical durations for implementation are: • Siting and approvals (up to five years) • Design and construction (about five years) • Initial fuel receipt (transfer of fuel from existing interim storage to new long-term storage facilities would occur over a period of approximately 35 to 40 years) • Extended monitoring (beyond 50 years) • Building refurbishment and fuel repackaging (beyond 50 years)
Costs	Depending on the specific design, preliminary cost estimates suggest this approach would cost between $17.6 billion and $25.7 billion (2002 dollars) for one 300-year cycle. Regardless of the storage options selected, the costs for reactor site extended storage would continue indefinitely. The present value cost of the first repeat cycle is approximately $2.3 to $4.4 billion (2004 dollars) based on current long-term economic factors. The calculation of costs beyond 300 years requires the use of long-term economic forecasting. (www.nwmo.ca/reactorcosts)

Option 3: Centralized Storage, Above or Below Ground

Option 3: Centralized Storage, Above or Below Ground

The management approach:

- Long-term management of used nuclear fuel in a storage facility, above or just below ground, at a central site in Canada;
- Used nuclear fuel is transported from the nuclear reactor sites to this central location for long-term management; and
- The storage facility is maintained, rebuilt and operated in perpetuity at this central site.

The illustrative timelines and activities associated with the concept are summarized in the table on the next page.

The detailed technical description, presented for the conceptual designs, are provided at www.nwmo.ca/centralstorage.

Figure 4-5 **Centralized Storage – Above Ground**

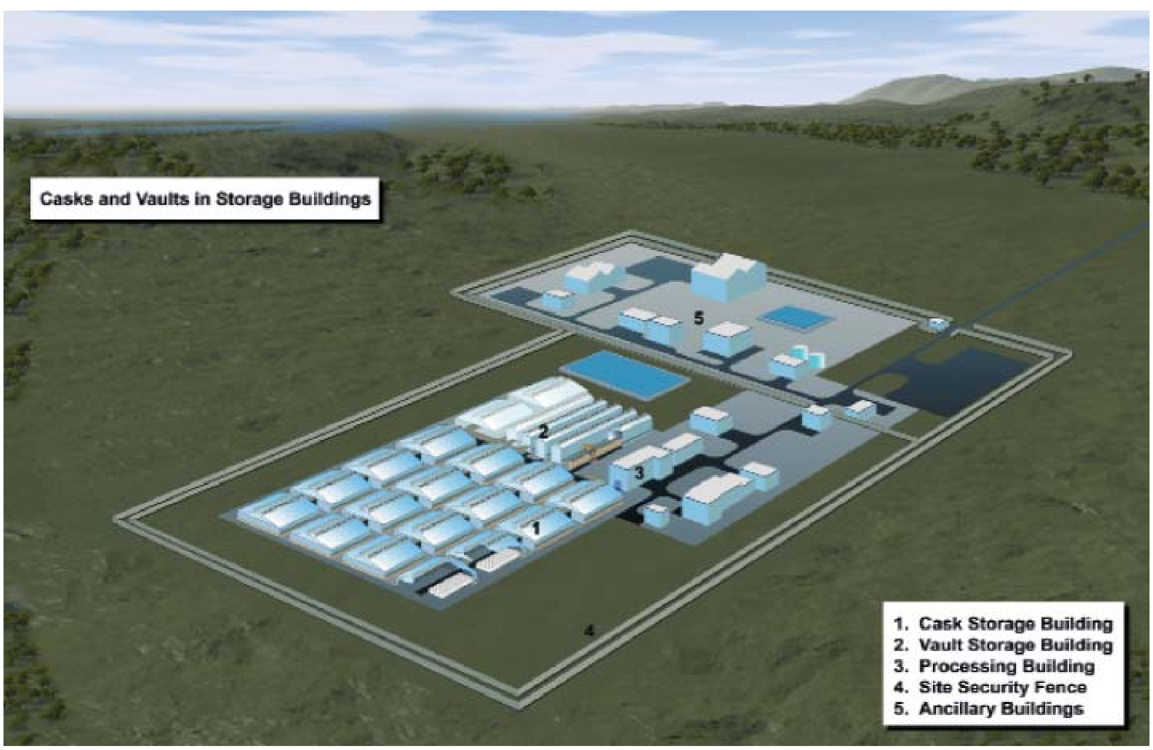


Table 4-4 Option 3: Centralized Storage, Above or Below Ground

Representative Conceptual Design	
Concept	Centralized extended storage involves creating new, long-term storage facilities at a central location. Used fuel would be transferred from the seven interim storage sites in Canada to a newly designed facility. Conceptual designs have been developed for a central storage facility built above ground, or below ground. There would need to be transportation containers and facilities to produce them; processing facilities to load the fuel into transportation containers; production facilities for storage containers; and processing facilities to transfer the fuel from transportation to storage containers. Storage would require an ongoing program of regular replacement and refurbishing activities, as facilities would be renewed and expanded indefinitely. Once all the used fuel is transferred to the long-term storage facilities, ongoing maintenance, inspections and security systems would be required.
Location	Centralized storage could be built at a nuclear reactor site, but for assessment purposes, it is conservatively assumed that the central storage facility would be located at an undeveloped site, and the facility would be expanded as needed. A specific location would need to be identified, and approvals would be required from the CNSC for construction and operation. This would also involve an environmental assessment.
Transportation Requirements	The operation of a centralized long-term storage facility would involve moving the fuel from existing reactor site storage facilities in certified transport containers to the central site over a period of approximately 30 years. Transportation will require an emergency response plan and adherence to security provisions. The mode of transportation (road, rail or water) would depend upon the location of the central facility and other factors.
Storage Design Life	The storage containers and storage facilities are designed to last at least 100 years. Based on current design assumptions, complete refurbishment of all components, and repackaging of the entire fuel storage system is assumed to be repeated every 300 years. For design purposes, the assumed service lives for the various storage facility components are: • Casks 100 years • Fuel module 300 years • Fuel basket 300 years • Trench chamber 200 years • Storage building 100 years • Processing building 50 years It is recognized that new designs may make possible extended service lives of the facilities.
Containers	We present four alternatives that have been developed by the Joint Waste Owners as representative of a range of possible designs for the centralized long-term storage facility concept. In all cases, the used fuel would be contained in either concrete and steel casks or vaults. Two alternatives would use buildings on the surface. The other two alternatives would be underground. One option would be just below the surface and mounded over, while the other option would be about 50 metres below ground in bedrock. The four design alternatives for centralized storage are: • Casks and vaults in storage buildings. • Surface modular vaults. • Casks and vaults in shallow trenches. • Casks in rock caverns. Facilities will exist at the central site for repackaging the used fuel.

Table 4-4 (cont'd) Option 3: Centralized Storage, Above or Below Ground

Representative Conceptual Design	
Underground Facility	No deep facility. The possibility exists to construct shallow rock caverns below the surface.
Repository Sealing System	None.
Geosphere Barrier	None. Geosphere would not provide a significant long-term isolation barrier.
Monitoring And Retrieval	The operation would require ongoing preventive maintenance and repair, as well as continuous monitoring to ensure that facility safety was being maintained. The long-term storage facilities would be designed to allow safe retrieval of used nuclear fuel at any point during the service life of the facility. If the storage systems did not perform as expected, they could be repaired, or the fuel could be transferred to a new storage facility.
Implementation Schedule	If the government moved in 2006 to adopt centralized storage, the storage facilities could not likely be ready for operations before 2023. Such facilities would require refurbishment or replacement by about the year 2300. The major phases and their typical durations for implementation are: • Siting (up to 10 years) • Design and construction (about 10 years) • Initial fuel receipt (up to 40 years) • Extended monitoring (beyond 50 years) • Building refurbishment and fuel repackaging (beyond 50 years) There will be a need to obtain a licence at each phase and demonstrate continuous compliance with the licence (under regulatory oversight).
Costs	Depending on the specific design, preliminary cost estimates suggest this approach would cost between $15.7 and $20.0 billion (2002 dollars) for one 300-year cycle, including interim used fuel storage and retrieval from reactor sites and transportation costs. The present value impact of the first cycle is approximately $3.1 to $3.8 billion (2004 dollars) based on current long-term economic factors. The calculation of costs beyond 300 years requires the use of long-term economic forecasting with its inherent uncertainties.(www.nwmo.ca/centralstoragecosts)

Option 4: Adaptive Phased Management

Option 4: Adaptive Phased Management (Recommended Approach)

The management approach:

- Long-term management of used nuclear fuel through an adaptive path which provides for:
  > centralized containment and isolation of the used fuel in a deep geologic repository in a suitable rock formation, such as the crystalline rock of the Canadian Shield or Ordovician sedimentary rock;
  > flexibility in the pace and manner of implementation through a phased decision-making process supported by a program of continuous learning, research and development;
  > provision for an interim step in the implementation process in the form of shallow underground storage of used fuel at the central site, prior to final placement in a deep repository;
  > continuous monitoring of the used fuel to support data collection and confirmation of the safety and performance of the repository; and
  > potential for retrievability of the used fuel for an extended period, until such time as a future society makes a determination on the final closure and the appropriate form and duration of postclosure monitoring.

- Used nuclear fuel is transported from the nuclear reactor sites to this central location for long-term management.

- The repository would be monitored to support data collection and confirmation of the safety and performance of the repository.

With the benefit of significant analysis and public engagement, and careful examination of the three options specified for study in the *NFWA*, we put forward a fourth option, our recommended management approach.

Option 4 combines features from the other three technical methods. It proposes a path forward toward a determinate end point, the placement of used nuclear fuel in a deep repository for safe, secure long-term management.

Here we present one possible way of proceeding down the path which involves movement of used fuel from nuclear reactor sites to a centralized underground storage facility in shallow rock caverns, followed by transfer to the final deep repository. At the same time, we acknowledge the long timelines associated with implementation. During this period, there will be an opportunity to adjust the pathway as may be appropriate with the benefit of new information, continuous learning, monitoring of research and technological developments and discussion of timelines most appropriate for communities affected by the transition to long-term management.

Many decisions may be influenced over the implementation period, including:

- Decisions on timelines on when to move fuel from nuclear reactor sites, where it is presently stored, to a centralized facility;

- The duration of underground research at the selected site;

- Whether to construct centralized storage as an interim step on the pathway to the final deep repository;

- The timing of construction of the deep repository, and placement of used fuel; and

- The timing of closure of the deep repository.

Our recommendation proposes a preferred technical method. In addition, it advances a full management approach, based on a socially responsible path forward toward the safe, secure isolation of used nuclear fuel for the very long term. We are proposing a path that demands responsible first steps, directed toward an end-point of secure isolation that we believe best provides for long-term safety and security.

The illustrative timelines and activities associated with the concept are summarized in the table below. A more detailed description is found in Appendix 3.

The detailed technical description, based on conceptual designs, is available at www.nwmo.ca/assessments.

Table 4-5 Option 4: Adaptive Phased Management

Representative Conceptual Design	
Concept	A staged management approach with three 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 **Phase 1 (approximately the first 30 years):** 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. Continue engagement with regulatory authorities to ensure pre-licensing work will be suitable for the subsequent licensing processes. 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. Initiate licensing process, which triggers the environmental assessment process under the *Canadian Environmental Assessment Act.* Undertake safety analyses and environmental assessment to obtain the required licenses 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. Develop and certify transportation containers and used fuel handling capabilities. 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. If a decision is made to construct shallow underground storage, obtain an operating licence for the storage facility. **Phase 2 (approximately the next 30 years):** 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. Complete the final design and safety analyses to obtain the required operating licence for the deep repository and associated surface handling facilities. There may be a need for transportation containers and facilities to produce them; processing facilities to load the fuel into transportation containers; production facilities for storage containers; processing facilities to transfer the fuel from transportation to storage containers. **Phase 3 (beyond approximately 60 years):** 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. 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 postclosure monitoring of the system. There may be a need for production facilities for used fuel containers; processing facilities to transfer the fuel from storage to deep repository; and production facilities for sealing materials.
Location	The central facility for the shallow rock cavern, underground research laboratory and deep repository could be located in a suitable rock formation such as the crystalline rock of the Canadian Shield or in the Ordovician sedimentary rock basins. These two rock types cover a vast amount of land reaching a significant portion of six provinces and two territories. A specific location would need to be identified and approval would be required from the Canadian Nuclear Safety Commission for the construction and operation of the facility. This would also involve an environmental assessment.
Transportation Requirements	The operation of a central facility would involve moving the fuel from existing reactor site storage facilities in certified transport containers to the central site over a period of approximately 30 years. Transportation will require an emergency response plan and adherence to security provisions. The mode of transportation (road, rail or water) will depend on factors such as the location of the central facility. The timing of transportation would depend on whether or not a shallow underground storage facility has been constructed at the central site and other factors.

Table 4-5 (cont'd) Option 4: Adaptive Phased Management

Representative Conceptual Design	
Containers	Storage containers at reactor sites will consist of the existing casks, vaults and silos. Storage containers at the central facility are based on the existing design of the dry storage container or equivalent with a 100-year design life. Containers for long-term isolation in a deep repository are based on a 100,000-year design life. These durable containers are designed to withstand long-term environmental effects such as climate change and glaciation. Facilities will exist at the central site for repackaging the used fuel.
Underground Facilities	During the Phase 2 extended storage period, the central facility would store used fuel in a series of shallow rock caverns excavated at a nominal depth of 50 metres below surface. During the Phase 3 long-term isolation period, the central facility would place used fuel in a network of horizontal tunnels and rooms excavated in stable rock at a nominal depth of 500 to 1,000 metres below surface. Used fuel containers would be placed within the rooms or in boreholes drilled into the floor of the rooms. Used fuel containers are assumed to be placed in a deep repository over a 30-year operating period.
Repository Sealing System	Clay-based materials would be used to surround and protect the containers, to fill the void spaces in the repository, to limit the movement of groundwater and dissolved material, and to protect workers during container placement operations. These are referred to as sealing systems, and involve materials such as high-performance concrete and swelling bentonite clay.
Geosphere Barrier	The geosphere, or host rock, provides the principal barrier between the used fuel containers and the surface environment. Both the crystalline rock of the Canadian Shield and the Ordovician sedimentary rock basins are examples of naturally occurring geologic formations which have long-term stability, good rock strength, low groundwater flow, and large areas exist with sufficient depth below the surface and lacking in mineral resources such that they are very unlikely to be disturbed by erosion or accidental drilling.
Monitoring and Retrievability	Used fuel would be monitored in the central shallow rock caverns and in the deep repository. During Phase 2, monitoring and retrieval would be straightforward over the 30-year period since the storage containers are readily accessible. During Phase 3, monitoring and retrieval over an estimated 240-year period would require more effort and technology since the long-term isolation containers would be backfilled and sealed within the placement rooms. Monitoring would be conducted to confirm the long-term safety and performance of the repository system. Until a decision is made to backfill and seal the access to the deep repository, monitoring would take place in-situ at repository depth. After closure of the deep repository around 300 years, postclosure monitoring of the facility could take place from the surface.
Implementation Schedule	A government decision in 2006 to select this management approach would see a new central shallow rock cavern storage facility and underground research laboratory ready by about 2035, and the deep geologic repository ready by about 2065. Following a decision by the federal government, the major steps in implementing this management approach include: • Siting of central facilities (about 20 years) • Design and construction of shallow underground storage caverns and underground research laboratory (about 10 years) • Transportation to central facility (over about 30 years) • Placement in deep geologic repository (over about 30 years) • Extended monitoring (out to 300 years) • Decommissioning and closure (over about 25 years) • Postclosure monitoring (indefinite) There will be a need to obtain a licence at each phase and demonstrate continuous compliance with the licence (under regulatory oversight).
Costs	The cost of this management approach for used nuclear fuel is conservatively estimated to be about $24 billion (2002 dollars), including interim used fuel storage and retrieval from reactor sites, transportation costs to the central facility, extended storage in underground caverns, technology research development and demonstration in the underground research laboratory and placement of used fuel in a deep geologic repository. These costs include the development and demonstration of the technology to retrieve used fuel from the deep repository, but not the costs to perform retrieval operations from the deep repository. The present value cost based on current long-term economic factors is approximately $6.1 billion (2004 dollars). (www.nwmo.ca/assessments). These costs include construction and operation of the shallow underground storage facility at the central site. If, however, the used fuel remains at the reactor site prior to operation of the deep repository and is not first placed in shallow storage, these costs would be reduced to about $22 billion (2002 dollars) with a present value of about $5.1 billion (2004 dollars).

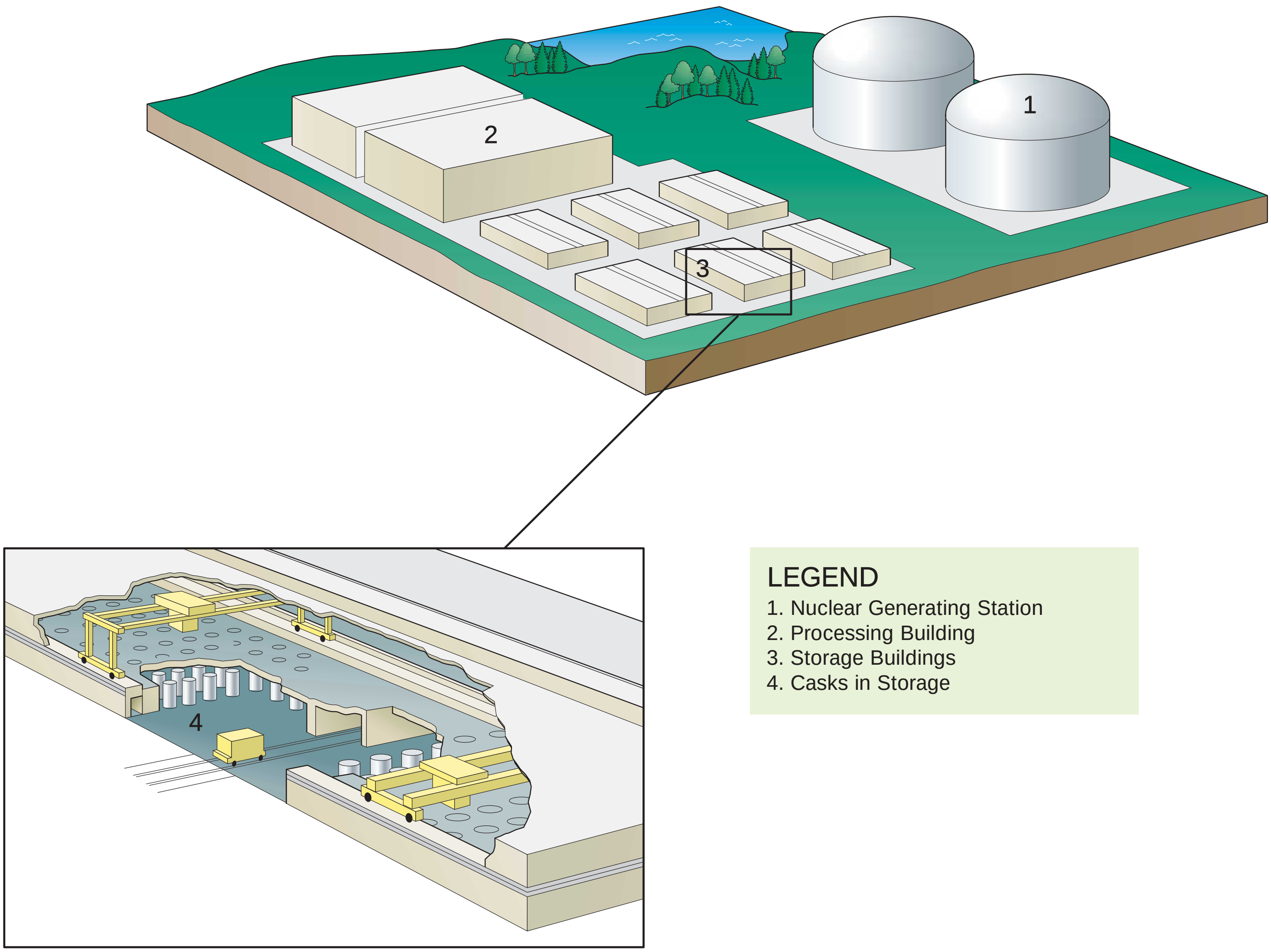
Figure 4-6 Adaptive Phased Management: Phase 1

Phase 1

Preparing for Central Used Fuel Management (Year 01 to Year 29):

Maintain storage and monitoring of used fuel at nuclear reactor sites while locating a site for a central management facility which has rock formations suitable for shallow underground storage, an underground research laboratory and a deep geologic repository. Continue research for used fuel management and incorporate citizen input, new learning and technology improvements. Complete safety analyses and environmental assessment to obtain the required licences and approvals to construct the central facilities at the preferred site and to transport used fuel.

Phase1



LEGEND
1. Nuclear Generating Station
2. Processing Building
3. Storage Buildings
4. Casks in Storage

Conduct further site characterization and design of central facilities. Initiate the licensing process. With public engagement and safety analyses, perform an Environmental Assessment that includes shallow rock cavern storage, the Underground Research Laboratory and deep geologic repository, and apply for Site Preparation Licence.

With Engagement Program, decide whether or not to construct centralized storage facility and transport used fuel to the central facility.

If **no**, maintain used fuel storage at reactor sites. Transport used fuel to central site in Phase 3.

If **yes**, obtain Construction Licence for shallow underground storage.

Obtain Construction Licence for Underground Research Laboratory.

YEAR 20

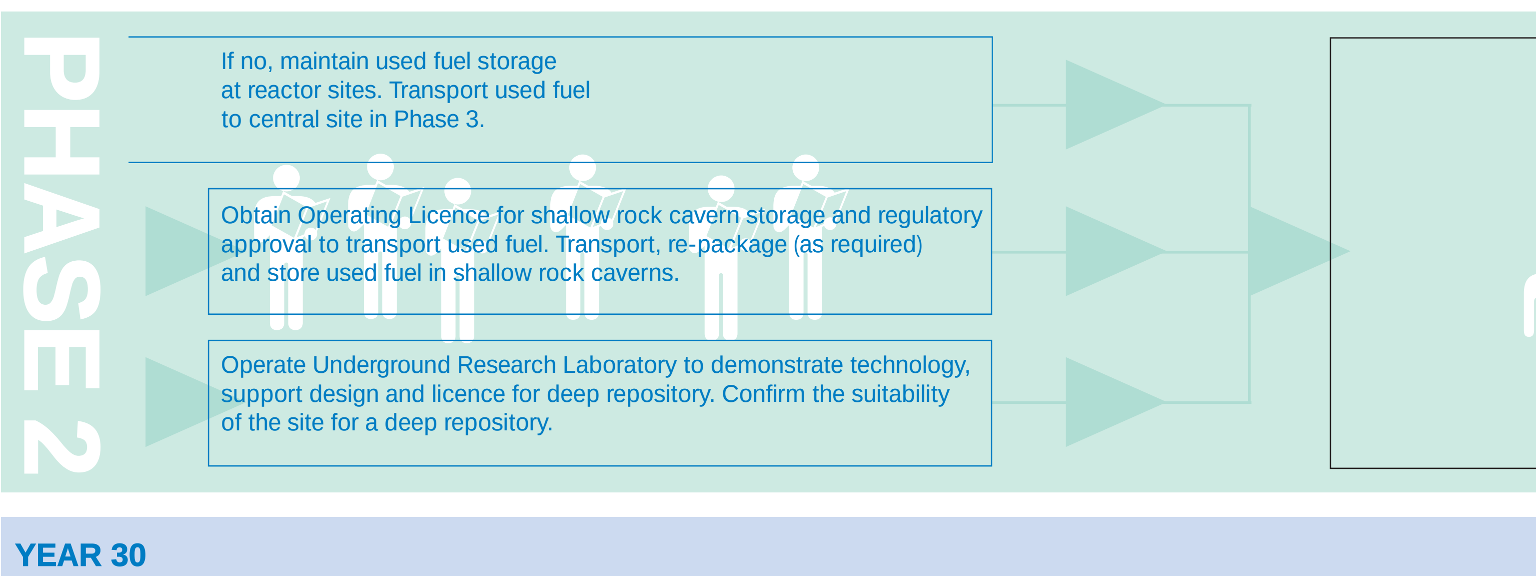
Figure 4-7 Adaptive Phased Management: Phase 2

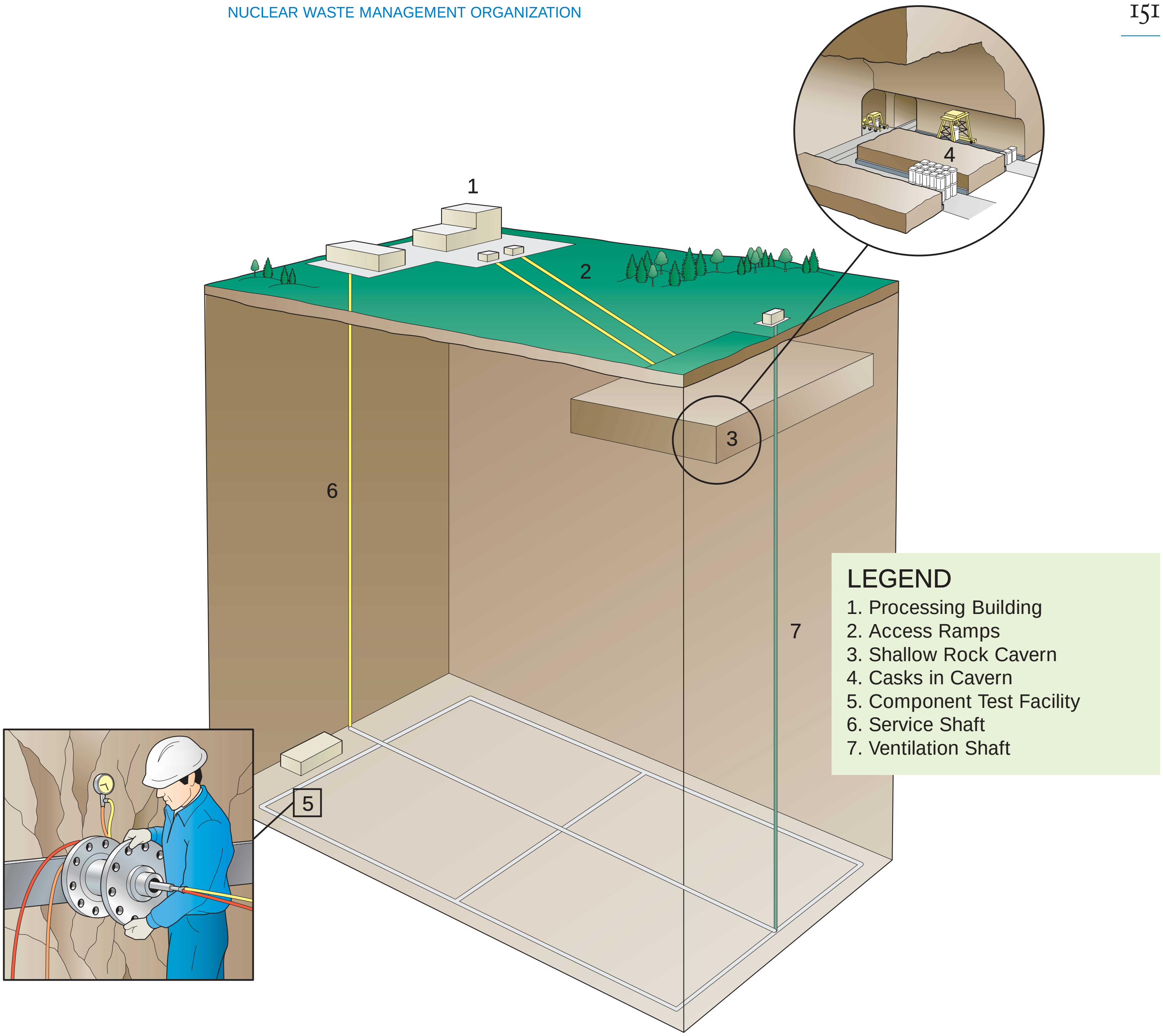
Phase 2

Central Storage and Technology Demonstration (Year 30 to Year 59):

Begin transport of used fuel from the reactor sites to the central facility and place used fuel in shallow underground storage, as required. Continue monitoring used fuel. Further develop and demonstrate long-term isolation technology at the underground research laboratory to confirm the suitability of the site and method. Prepare the final design, safety analyses and facilities to obtain the required operating licence for the deep repository.

Phase2





Used fuel is safely stored until society is ready to proceed with next step.

Through the Engagement Program, prepare final design and **decide** when to construct the deep repository and ancillary facilities. Obtain Construction Licence for deep repository.

YEAR 50

Figure 4-8 **Adaptive Phased Management: Phase 3**

Phase 3

Long-term Containment, Isolation and Monitoring (Year 60 to Y???)

Retrieve used fuel from shallow underground storage, repackage it into long-lived containers and transfer the containers to a deep geologic repository at the central site. Maintain access to the deep repository, continue monitoring and allow retrieval of used fuel, if required. Provide the option for a future society to close the repository, decommission the facility and continue monitoring of the system while ensuring long-term passive safety and security for humans and the environment.

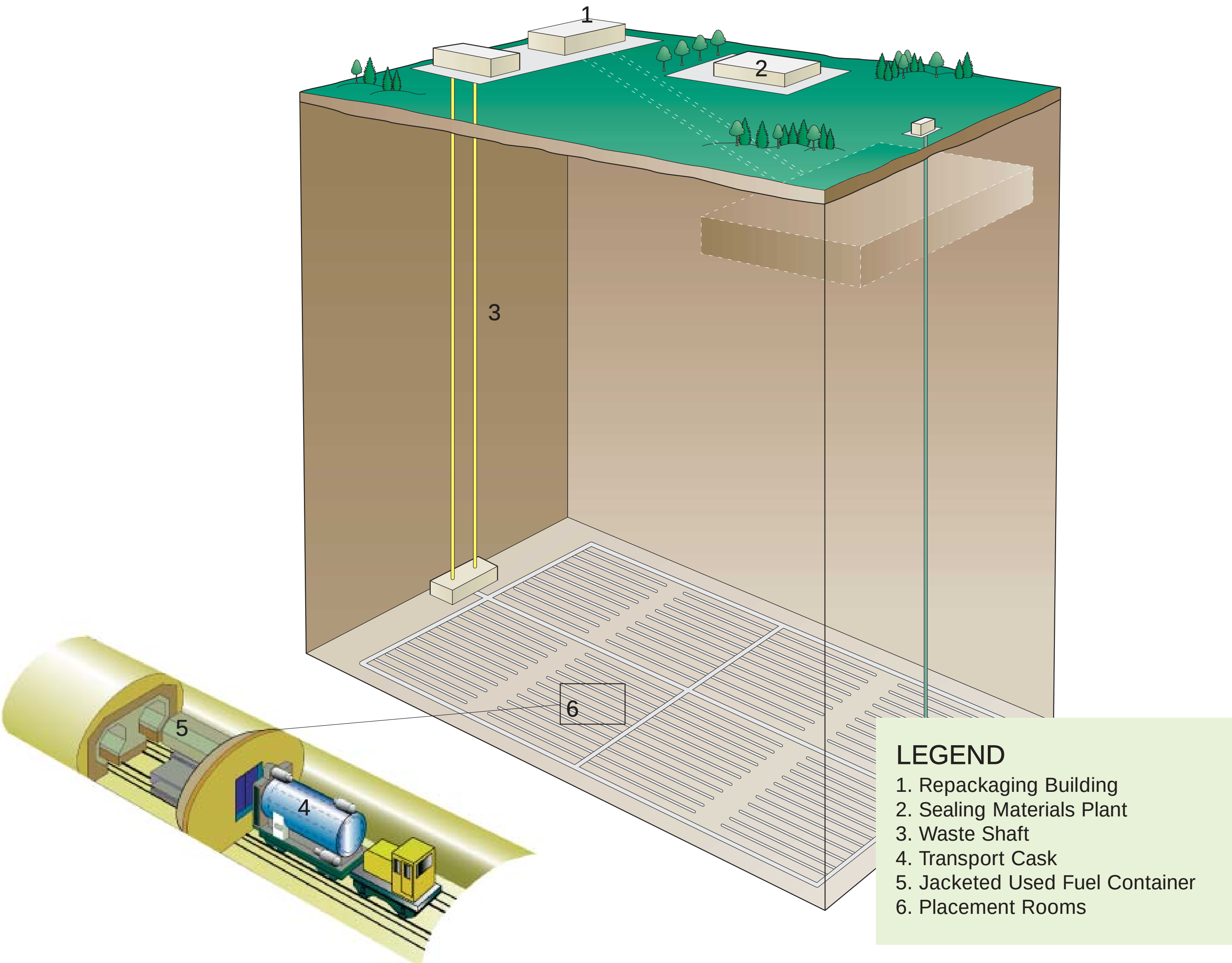
Phase3

PHASE 3

Obtain Operating Licence for deep geologic repository. Transport used fuel, as required. Package and place used fuel in deep repository and begin extended in-situ monitoring.

Used fuel is now fully placed in repository.

YEAR 60 **YEAR 90**



Monitoring will continue until a future society is sufficiently confident that the used fuel will remain contained and isolated.

Decide when to close and decommission deep geologic repository.

Close access tunnels and shafts. Postclosure monitoring may be implemented if desired.

YEAR 300

CHAPTER 9 / ECONOMIC REGIONS FOR IMPLEMENTATION

Nuclear Fuel Waste Act (*NFWA*) reference:
12. (3) The study must include a detailed technical description of each proposed approach and must specify an economic region for its implementation.

Although we are not proceeding with site selection as part of this study, we have an obligation under the *Nuclear Fuel Waste Act* (*NFWA*) to address economic regions for implementation of each of the approaches in our study.

The *NFWA* defines an 'economic region' as that described by Statistics Canada in its *Guide to the Labour Force Survey*, published on January 31, 2000. Economic regions are broad-based geographic units, generally composed of several census divisions within a province, used for compiling statistics and analysis of regional economic activity.

The 2000 Survey described 73 regions. Presently, there are 76 economic regions in Canada, including the Yukon, Northwest Territories and Nunavut regions.

Having listened to Canadians, we believe that objectives of safety and fairness should be central in guiding locational decisions for the management approach. These objectives underlie our proposals with respect to the specification of economic regions and our proposed siting considerations, outlined in Sections 9.2 and 9.3 respectively.

In addressing the legislative requirements, the *NFWA* does *not* require us to identify a particular region for implementing each management approach. This is appropriate for a number of reasons.

- Storage at nuclear reactor sites (Option 2) would, by definition, require implementation in a number of different regions. Similarly, centralized approaches (Options 1, 3 and 4) through their transportation requirements, would involve implementation in more than one region;
- Siting characteristics for any centralized facility would need to take into account, among other things, the suitability of a location in terms of its geotechnical and environmental characteristics. These characteristics differ vastly within regions, making it difficult to propose economic regions without site investigation. Screening out economic regions during the conceptual study phase, without the benefit of site characterization, would risk prematurely eliminating potential candidate regions from consideration; and
- Finally, we believe that the preferred site for any new facility must take into account a number of factors that will determine its suitability for ensuring our objectives of safety and security. Many social, environmental, physical and technical siting factors must be taken into account in site selection, as we discuss in Section 9.3. Narrowing the number of economic regions at this time may unduly remove communities that might otherwise wish to be considered as a potential host location.

9.1 / What We Can Learn from Economic Regions

We have done our best to specify regions that we believe to have potentially suitable locations for implementing different types of management approaches, and have done so to the extent we believe practicable at this time. We report on our specification of economic regions in Section 9.2.

It is useful to examine economic regions to understand how implementation might differ according to the location. As part of our study, we examined in some depth the implications of situating a facility in different types of regions that reflect a diversity of human and biophysical characteristics. We looked at a range of economic regions, for purely illustrative purposes, as a means of understanding the costs, benefits and risks associated with locating a facility in regions with different physical, demographic and socio-economic features. We reported on this work in Part Three.

Through our analysis, we have seen that there is often as much variation within an economic region, as between regions, making it difficult to generalize about the suitability of one region over another.

A given economic region can exhibit vast differences in geology, environmental conditions, demographics and socio-economic composition. It is difficult to generalize beyond a certain point about the suitability of a particular region. For example, it is possible that an economic region might include both areas of stable geology, and areas that would be considered seismically unstable. In such cases, it would be inappropriate to exclude from consideration the region in its entirety.

We do not believe that we can proceed to further narrow the scope of possible regions for implementation at this time. Economic regions are not designed around meaningful boundaries for purposes of engaging in discussion around possible host communities. They do not reflect political or legal boundaries. Nor do they represent boundaries of traditional Aboriginal territories, or our country's ecozones. As a population, we do not organize our communities around the units of economic regions. We may have just as much or more in common with communities in neighbouring regions, as with communities located in other areas within our own defined economic region.

Ultimately, decisions on locating a facility will be made based on site-specific characteristics, and not economic regions. Following a government decision on a management approach, implementation planning will transition from this discussion of broad economic boundaries, to one that considers specific siting characteristics defined for a fully specified project. Decisions will be guided by principles, objectives and processes that are developed collaboratively between the NWMO and interested locations. In Section 9.3 we address some of these considerations.

9.2 / Specification of Economic Regions

We believe that the objective of fairness would best be achieved if the site selection process is focused within the provinces that are directly involved in the nuclear fuel cycle. Accordingly, in specifying economic regions for centralized facilities, we have proposed that the process of implementation be in the provinces that have benefited from activity associated with the nuclear fuel cycle.

This includes the three provinces that generate electricity from nuclear power and consequently create used nuclear fuel as a by-product (Ontario, New Brunswick and Québec), as well as Saskatchewan, which has benefited economically from the mining of uranium that is used to make our used nuclear fuel. We believe that these provinces have a greater responsibility than do other provinces and territories to manage the waste stream arising from the nuclear process.

We recognize that communities in other regions and provinces, beyond the four nuclear provinces, may come forward with an interest in hosting a facility for a long-term management of used nuclear fuel. Provided that a site is shown to meet the established safety and other regulatory requirements, such regions would not be denied the opportunity to be considered as a potential host, with the commensurate positive economic spin-offs that may be associated with hosting the facility.

Option 1: Deep Geological Disposal in the Canadian Shield

The *NFWA* definition of disposal confines this approach to the economic regions lying in the Canadian Shield.

Thus, by its definition, Option 1: Deep Geological Disposal in the Canadian Shield, brings the focus of implementation to the 21 economic regions which encompass the crystalline rock of the Canadian Shield, which stretches across six provinces and two territories.

Within this set of regions, we believe that our objective of fairness would best be achieved if the siting processes were focused in the economic regions in the provinces associated with the nuclear fuel cycle.

We recognize that communities in other regions and provinces on the Canadian Shield may come forward with interest in possibly hosting the facility. Such expressions of interest should also be considered.

More specific examination of the regions, against siting principles and scientific and technical siting requirements, would determine the potential suitability of these regions for implementation of Option 1.

In Table 4-6, we specify the economic regions that we propose be considered for possible implementation of Option 1: Deep Geological Disposal in the Canadian Shield.

Figure 4-9 **Option 1: Deep Geological Disposal in the Canadian Shield-Map**

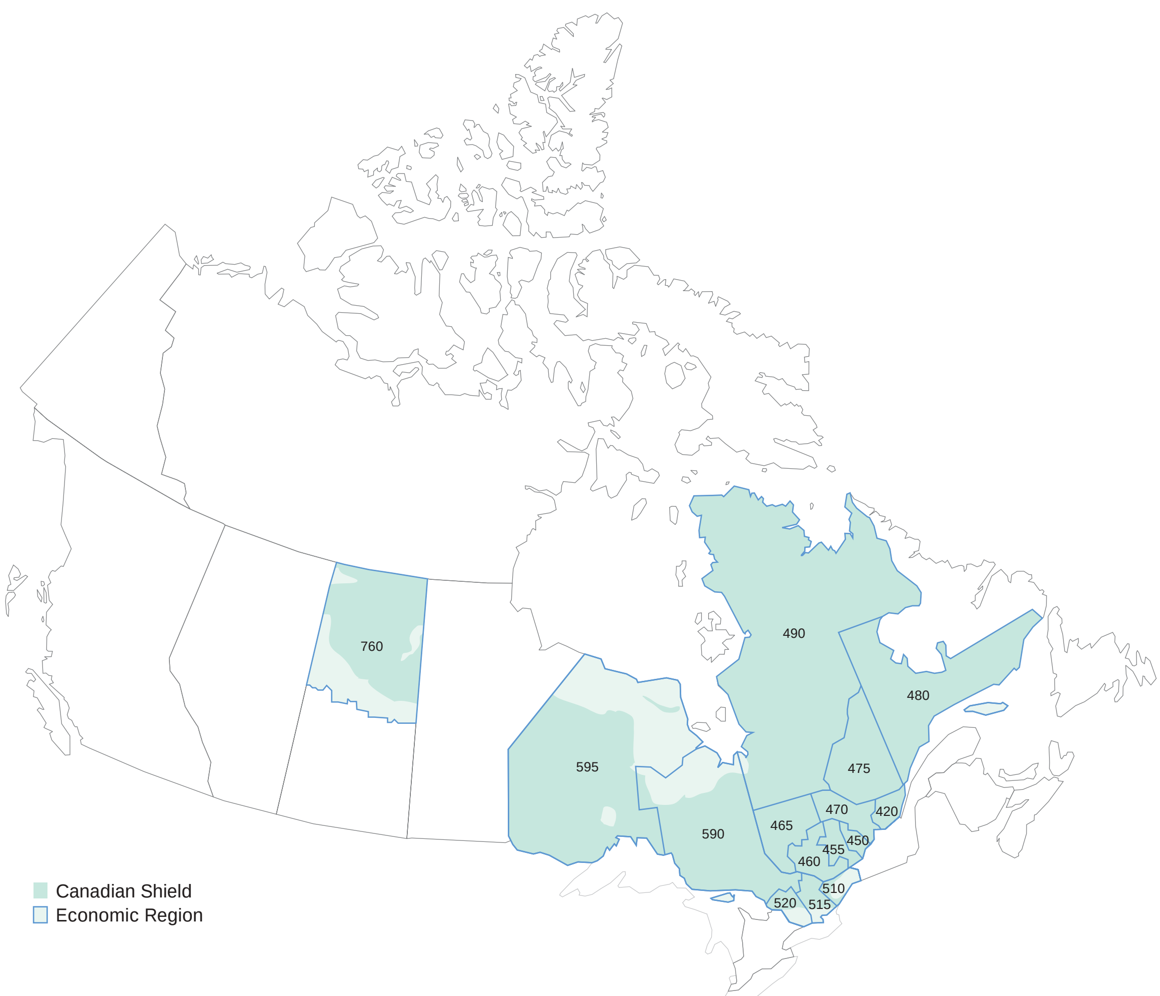


Table 4-6 Economic Regions for Possible Implementation of Option 1

The NWMO proposes specification of the following economic regions for possible implementation of Option 1: Deep Geological Disposal in the Canadian Shield.

Economic regions on the Canadian Shield that are within provinces associated with the nuclear fuel cycle:

QUÉBEC:

420:	Québec
450:	Lanaudière
455:	Laurentides
460:	Outaouais
465:	Abitibi-Témiscamingue
470:	Mauricie
475:	Saguenay-Lac St. Jean
480:	Côte-Nord
490:	Nord-du-Québec

ONTARIO:

510:	Ottawa
515:	Kingston-Pembroke
520:	Muskoka – Kawarthas
590:	Northeast
595:	Northwest

SASKATCHEWAN:

760:	Northern

Communities in other regions and provinces on the Canadian Shield may come forward with interest in possibly hosting the facility for Option 1. Such expressions of interest would also be considered.

Option 2: Storage at Nuclear Reactor Sites

Under Option 2: Storage at Nuclear Reactor Sites, used nuclear fuel would be stored at the sites presently hosting the nuclear reactors. Therefore, implementation of long-term storage at nuclear reactor sites would be specified for the six economic regions in which the existing seven nuclear reactor sites are located.

In Table 4-7, we specify the economic regions that would be considered for possible implementation of Option 2: Storage at Nuclear Reactor Sites.

Table 4-7 Economic Regions for Possible Implementation of Option 2

The NWMO proposes specification of the following economic regions for possible implementation of Option 2: Storage at Nuclear Reactor Sites.

Economic regions in which Canada's nuclear reactor sites are situated:

QUÉBEC:

433:	Centre-du-Québec (Gentilly Reactors)

ONTARIO:

515:	Kingston-Pembroke (Chalk River Laboratory Reactors)
530:	Toronto (Pickering and Darlington Reactors)
580:	Stratford-Bruce Peninsula (Bruce Power Reactors; AECL Douglas Point Reactor)

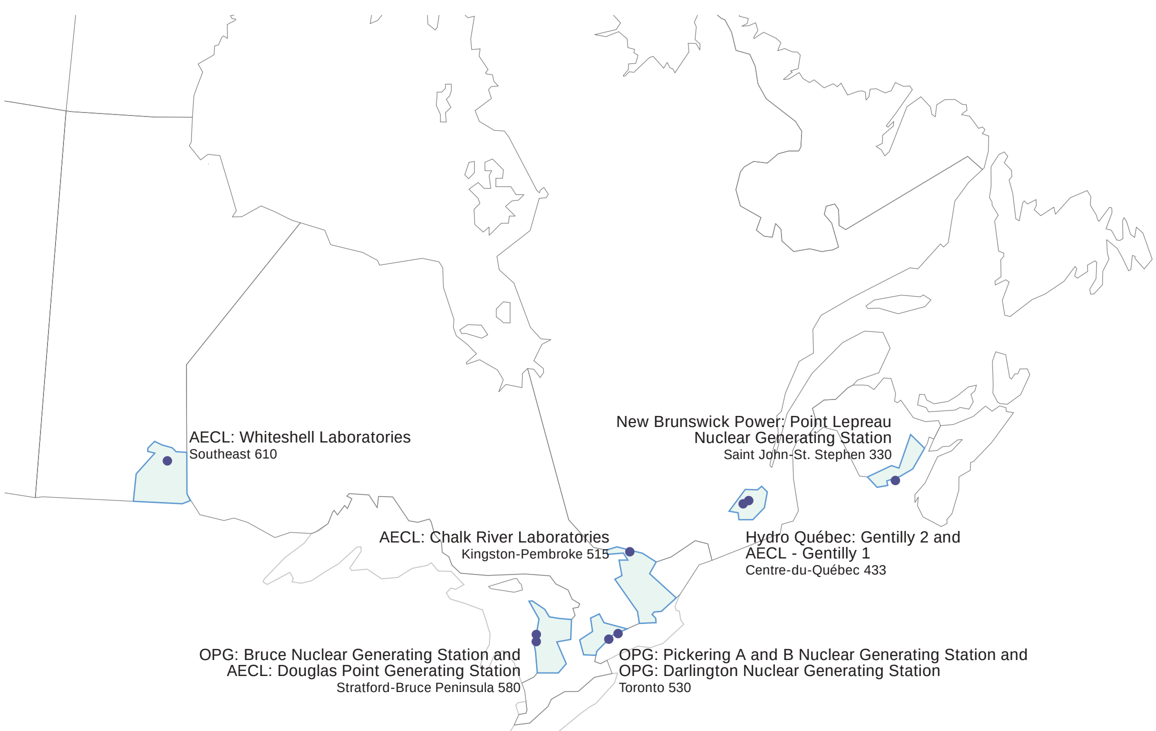
NEW BRUNSWICK:

330:	Saint John-St. Stephen (Point Lepreau Reactor)

MANITOBA:

610:	Southeast (Whiteshell Laboratories)

Figure 4-10 Option 2: Storage at Nuclear Reactor Sites-Map



Option 3: Centralized Storage (above or below ground)

The *NFWA* does not set out any criteria that would restrict Option 3 geographically. By its nature, centralized storage may be designed to be built above ground as well as slightly below ground surface.

Not reliant on specific geological requirements to enable the safe operation of this type of facility, other than required soil characteristics to support the storage facilities and associated infrastructure, this concept offers considerable flexibility in siting. The starting point is the complete set of 76 economic regions in Canada.

Within this set of regions, we believe that our objective of fairness would best be achieved if the siting processes were focused in the economic regions in the provinces associated with the nuclear fuel cycle.

We recognize that communities in other regions and provinces may come forward with interest in possibly hosting the facility. Such expressions of interest should also be considered.

More specific examination of the regions, against siting principles and scientific and technical siting requirements, would determine the potential suitability of these regions for implementation of Option 3.

In Table 4-8, we specify the economic regions that we propose be considered for possible implementation of Option 3: Centralized Storage (above or below ground).

Figure 4-11 **Option 3: Centralized Storage (above or below ground)-Map**

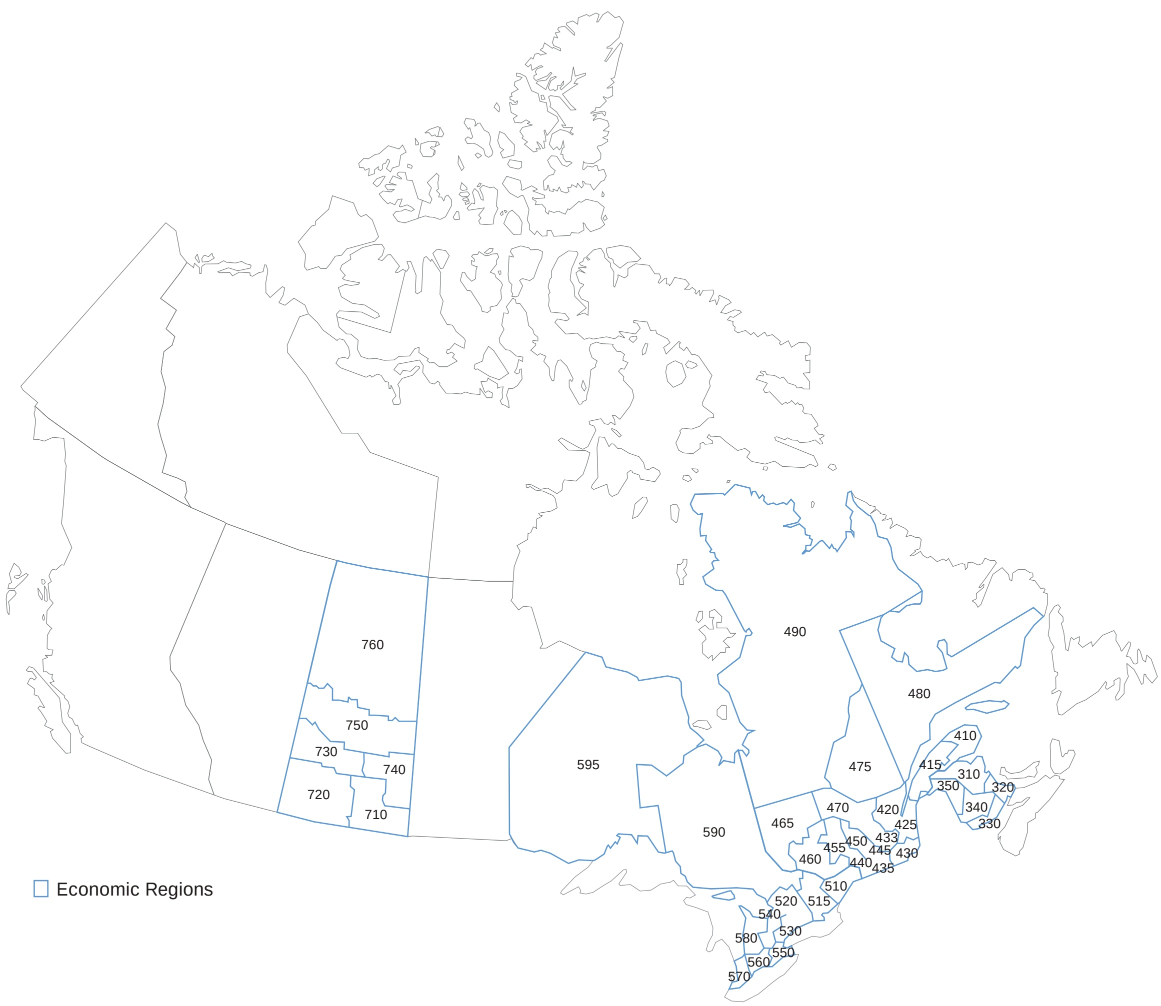


Table 4-8 Economic Regions for Possible Implementation of Option 3

The NWMO proposes specification of the following economic regions for possible implementation of Option 3: Centralized Storage, Above or Below Ground.

Economic regions within provinces associated with the nuclear fuel cycle:

NEW BRUNSWICK:

310:	Campbellton – Miramichi
320:	Moncton – Richibucto
330:	Saint John – St. Stephen
340:	Fredericton – Oromocto
350:	Edmundston – Woodstock

QUÉBEC:

410:	Gaspésie - Îles-de-la-Madeleine
415:	Bas-Saint-Laurent
420:	Québec
425:	Chaudière-Appalaches
430:	Estrie
433:	Centre-du-Québec
435:	Montérégie
440:	Montréal
445:	Laval
450:	Lanaudière
455:	Laurentides
460:	Outaouais
465:	Abitibi-Témiscamingue
470:	Mauricie
475:	Saguenay – Lac-Saint-Jean
480:	Côte-Nord
490:	Nord-du-Québec

ONTARIO:

510:	Ottawa
515:	Kingston – Pembroke
520:	Muskoka – Kawarthas
530:	Toronto
540:	Kitchener – Waterloo – Barrie
550:	Hamilton – Niagara Peninsula
560:	London
570:	Windsor – Sarnia
580:	Stratford – Bruce Peninsula
590:	Northeast
595:	Northwest

SASKATCHEWAN:

710:	Regina – Moose Mountain
720:	Swift Current – Moose Jaw
730:	Saskatoon – Biggar
740:	Yorkton – Melville
750:	Prince Albert
760:	Northern

Communities in other regions and provinces may come forward with interest in possibly hosting the facility for Option 3. Such expressions of interest would also be considered.

Option 4: Adaptive Phased Management

Phase 1 of Option 4 involves interim storage at nuclear reactor sites.

Phases 2 and 3 of this staged management approach would require selecting a site that would support deep geologic storage. The same site must also be suitable for shallow underground interim storage.

Sites to be considered would need to have the robust rock formations required to safely store and isolate used fuel perpetually, as envisaged in the design concept.

Canada is fortunate in that its vast geological resources present many options for locating a deep underground repository. Most notably, the 21 economic regions on the Canadian Shield may offer candidates sites. In addition, other rock formations such as the Ordovician sedimentary formations may prove to offer other robust sites for hosting a facility.

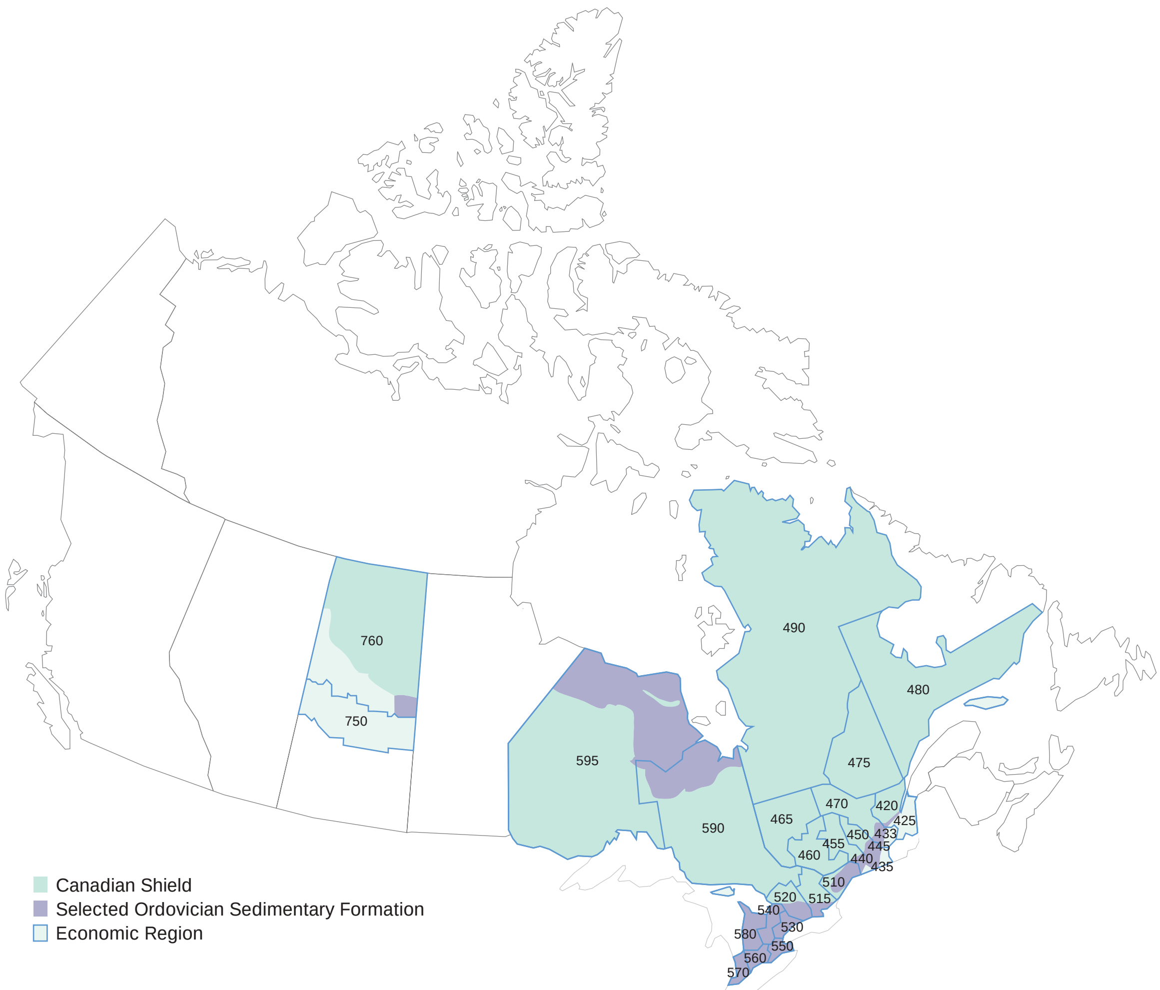
Within this set of regions, we believe that our objective of fairness would best be achieved if the siting processes were focused in the economic regions in the provinces associated with the nuclear fuel cycle. The attached map outlines the economic regions within those provinces that we believe present potentially suitable rock formations to support Phases 2 and 3 of implementation.

We recognize that communities in other regions and provinces may come forward with interest in possibly hosting the facility. Such expressions of interest should also be considered.

More specific examination of the regions, against siting principles and scientific and technical siting requirements, would determine the potential suitability of these regions for implementation of Option 4.

In Table 4-9, we specify the economic regions that we propose be considered for possible implementation of Option 4: Adaptive Phased Management.

Figure 4-12 **Option 4: Adaptive Phased Management-Map**



The NWMO specifies economic regions for implementation of:

- Phase 1: Regions presently hosting nuclear reactors
  > Economic regions with nuclear reactor sites.

- Phases 2 and 3: Regions with potentially suitable rock formations in the nuclear provinces, for example:
  > On the Canadian Shield; or
  > On selected Ordovician Sedimentary basins.

Table 4-9 **Economic Regions for Possible Implementation of Option 4**

<table>
<tr><td colspan="3">The NWMO proposes specification of the following economic regions for possible implementation of Option 4: Adaptive Phased Management</td></tr>
<tr><td>Economic regions at nuclear reactor sites:

Phase 1 Implementation</td><td colspan="2">Economic regions with rock formations potentially suitable for a centralized deep repository:

Phase 2 and 3 Implementation</td></tr>
<tr><td rowspan="3">List A:
6 Regions At Nuclear Reactor Sites

QUÉBEC:
433: Centre-du-Québec
(Gentilly Reactors)

ONTARIO:
515:Kingston-Pembroke
(Chalk River Laboratory Reactors)
530:Toronto
(Pickering and Darlington Reactors)
580:Stratford-Bruce Peninsula
(Bruce Power Reactors; AECL Douglas Point Reactor)

NEW BRUNSWICK:
330: Saint John-St. Stephen
(Point Lepreau)

MANITOBA:
610: Southeast
(Whiteshell Research Laboratory)</td><td colspan="2">Economic regions with potentially suitable rock formations, within provinces associated with the nuclear fuel cycle:</td></tr>
<tr><td>List B:
On the Canadian Shield:

QUÉBEC:
420: Québec
450: Lanaudière
455: Laurentides
460: Outaouais
465: Abitibi-Témiscamingue
470: Mauricie
475: Saguenay-Lac St. Jean
480: Côte-Nord
490: Nord-du-Québec

ONTARIO:
510: Ottawa
515: Kingston/Pembroke*
520: Muskoka–Kawarthas
590: Northeast
595: Northwest

SASKATCHEWAN:
760: Northern</td><td>List C:
On Selected Ordovician Sedimentary Formation:

ONTARIO:
510: Ottawa**
515: Kingston – Pembroke*
520: Muskoka – Kawarthas**
530: Toronto*
540: Kitchener-Waterloo-Barrie
550: Hamilton – Niagara
560: London
570: Windsor – Sarnia
580: Stratford-Bruce Peninsula*
590: Northeast**
595: Northwest**

QUÉBEC:
420: Québec**
425: Chaudière-Appalaches
433: Centre-du-Québec*
435: Montérégie
440: Montréal
445: Laval
450: Lanaudière**
455: Laurentides**
460: Outaouais**
470: Mauricie**

SASKATCHEWAN:
750: Prince Albert
760: Northern **

* Economic Region already captured in List A.
** Economic Region already captured in List B.</td></tr>
<tr><td colspan="2">Communities in other regions and provinces may come forward with interest in possibly hosting the facility for Option 4. Such expressions of interest would also be considered.</td></tr>
</table>

9.3 / Siting Principles and Other Factors

In specifying economic regions and in proposing principles for siting the management approaches, we are guided by the ethical principles identified in the course of the study. These are:

- Respect for life in all its forms, including minimization of harm to human beings and other sentient creatures;
- Respect for future generations of human beings, other species, and the biosphere as a whole;
- Respect for peoples and cultures;
- Justice across groups, regions, and generations;
- Fairness to everyone affected and particularly to minorities and marginalized groups; and
- Sensitivity to the differences of values and interpretations that different individuals and groups bring to the dialogue.

Based on these principles, we intend to seek a willing community to host the central facilities. In order for the site to be acceptable, it would need to address scientific and technical siting factors to ensure that any facility is likely to protect human beings, including future generations, other life-forms and the biosphere as a whole into the indefinite future. Any facility would be subjected to regulatory oversight to ensure that the site is acceptable from a safety perspective.

Based on these principles, the siting process will be designed to:

- Be open, inclusive and fair to all parties, giving everyone with an interest in the matter an opportunity to have their views heard and taken into account;
- Ensure groups most likely to be affected by the facility, including the transportation required, are given full opportunity to have their views heard and taken into account, and are provided with the forms of assistance they require to present their case effectively;
- Include special attention to Aboriginal communities that may be affected. In particular, the NWMO will respect Aboriginal rights, treaties and land claims;
- Be free from conflict of interest, personal gain or bias among those making the decision and/or formulating recommendations;
- Be informed by the best knowledge – in particular the best natural science, the best social science, the best Aboriginal knowledge, and the best ethics – relevant to making a decision and/or formulating a recommendation;
- Be in accord with the precautionary approach, which first seeks to avoid harm and risk of harm. If harm or risk of harm is unavoidable, place the burden of proving that the harm or risk is ethically justified on those making the decision to impose it;
- Ensure, in accordance with the doctrine of informed consent, that those who could be exposed to harm or risk of harm (or other losses or limitations) are fully consulted and are willing to accept what is proposed for them;
- Take into consideration, in so far as it is possible to do so, the costs, harms, risks, and benefits of the siting decision, including not just financial costs but also physical, biological, social, cultural, and ethical costs (harm to our values); and
- Ensure that those who benefited most from nuclear power (past, present and perhaps future) are bearing the potential costs and risks of managing used fuel and other nuclear materials.

Those potentially affected by the development of the management facility must be involved in discussions and be provided in advance with information that enables them to participate effectively. The implementation process must seek ways to assist citizens in the host community to manage the resulting change caused by the project so they can pursue their economic, social and cultural aspirations. Effects management measures will need to be used to avoid or reduce the severity of negative socio-economic impacts of hosting the facility while nourishing those that enhance desirable socio-economic and cultural characteristics.

We are particularly sensitive to the role of Aboriginal Peoples in the years ahead. We are committed to building a relationship based on mutual trust, respect, and integrity. We are committed to seeking an alignment between Aboriginal values and those reflected in our management strategy.

Safety will be central to all decision-making processes. Regulatory processes overseen by the Canadian Nuclear Safety Commission (CNSC) will lead the reviews of site locations. Environmental assessment and licensing procedures will demand that the safety case be clearly demonstrated. The CNSC, together with Transport Canada, will demand strong safety cases for any required transportation associated with implementation. For any management approach adopted, specific siting requirements will be defined once a decision has been taken on a specific approach, and the project specifications fully elaborated.

The scientific and technical siting factors will include:

For Option 1: Deep Geological Disposal in the Canadians Shield

- Location in the Canadian Shield;
- Absence of known potential economic resources at depth;
- Sufficient surface area for receipt facilities and associated infrastructure;
- Seismically stable region with low known or projected frequency of high magnitude earthquakes;
- Low frequency of major groundwater conducting fracture zones, features or faults at repository depth;
- Geotechnically suitable host rock formation at least 200 metres below surface with a preference for a suitable host rock formation between 500 and 1,000 metres below surface for the deep geologic repository;
- Geochemically suitable (e.g., reducing) conditions in groundwater at repository depth;
- Evidence of rock mass homogeneity and stability at repository depth;
- Low hydraulic gradient and low permeability; and
- Diffusion controlled transport of dissolved minerals at repository depth.

For Option 2: Storage at Nuclear Reactor Sites

- Location of storage facilities at nuclear reactor sites.

For Option 3: Centralized Storage, Above or Below Ground

- Competent soil or similar material to support the storage facilities and associated infrastructure;
- Sufficient surface area for storage facilities and associated infrastructure; and
- Seismically stable region with low known or projected frequency of high magnitude earthquakes.

For Option 4: Adaptive Phased Management

- Location in suitable rock such as the crystalline rock of the Canadian Shield or in the Ordovician sedimentary rock basins;
- Absence of known potential economic resources at depth;
- Sufficient surface area for receipt facilities and associated infrastructure;
- Seismically stable region with low known or projected frequency and magnitude of earthquakes;
- Low frequency of major groundwater conducting fracture zones, features or faults at repository depth;
- Geotechnically suitable host rock formation below surface for the shallow rock cavern vaults;
- Geotechnically suitable host rock formation at least 200 metres below surface with a preference for a suitable host rock formation between 500 and 1,000 metres below surface for the underground research laboratory and the deep geologic repository;
- Geochemically suitable (e.g., reducing) conditions in groundwater at repository depth;
- Evidence of rock mass homogeneity and stability at repository depth;
- Low hydraulic gradient and low permeability; and
- Diffusion controlled transport of dissolved minerals at repository depth.

CHAPTER 10 /
COMPARISON OF BENEFITS, RISKS AND COSTS

Nuclear Fuel Waste Act (*NFWA*) reference:
12. (4) Each proposed approach must include a comparison of the benefits, risks and costs of that approach with those of the other approaches, taking into account the economic region in which that approach would be implemented, as well as ethical, social and economic considerations associated with that approach.

The *Nuclear Fuel Waste Act* (*NFWA*) requires us to undertake a comparative assessment of management approaches.

In Chapters 3 and 4, we describe the management approaches selected for consideration in our study:

Option 1: Deep Geological Disposal in the Canadian Shield
Option 2: Storage at Nuclear Reactor Sites
Option 3: Centralized Storage, either above or below ground
Option 4: Adaptive Phased Management

Building on "sustainable development" as the conceptual underpinning for the assessment of management approaches, we committed to "develop collaboratively with Canadians a management approach for the long-term care of used nuclear fuel that is socially acceptable, technically sound, environmentally responsible and economically feasible."

We wanted our assessment of the options to be guided by the values and expectations of Canadians in general, and be informed by the wealth and knowledge of a broad spectrum of experts. Our collaborative development of the assessment framework drew on the input of Canadians, and a wide range of technical expertise.

We conducted an extensive process of public engagement with the general public and with Aboriginal Peoples. We convened a national dialogue on fundamental values and ethics. In Part Two, we report on these dialogue processes.

We synthesized and considered a vast body of accumulated information – technical, social, environmental, financial.

We reviewed the range of potential management options. Through an iterative process and dialogue with citizens, we identified those that would become the focus of our initial study: Deep Geological Disposal in the Canadian Shield; Storage at Nuclear Reactor Sites; and Centralized Storage.

Once the foundations for our assessment were laid, we subjected the options to multiple analytical processes.

- We began by assessing the three approaches through a multi-attribute utility analysis. We convened an Assessment Team to undertake this preliminary examination of the three approaches. In applying a systems approach, the Team identified the strengths and limitations of each of the three approaches on each of eight objectives;

- We built upon this assessment through broad dialogue;

- We reflected on the assessment of the three approaches specified in the *NFWA*, and we listened to the commentary received from our engagement process with the general public and Aboriginal Peoples.

From this work, we developed a fourth option, Adaptive Phased Management, which we proposed for inclusion in our study;

- We subjected all four management approaches to a detailed cost, benefit and risk assessment, taking into account economic regions. The analysis introduced further information on how each approach performed against the eight objectives. The analysis brought quantitative analysis and models to bear in understanding how each of the four approaches compared against our objectives. It contributed further qualitative insights, to help broaden our understanding of costs, benefits and risks. Importantly, it included socio-economic analysis of the implications for the different types of economic regions that might host the facilities; and

- In our assessments, we considered the management options against two time periods: the near term, which was defined as one to 175 years; and the long term, which was defined as greater than 175 years. And we considered a range of plausible scenarios for how the future might unfold.

In Part Three, we report on the development of our assessment framework and the findings of our assessment of the management approaches.

All of the supporting reports, papers and assessment studies are available for review on our website. (www.nwmo.ca)

IMPLEMENTATION

For any management approach selected, the decision-making and implementation processes will involve at least many decades. As we proceed with the implementation path, it will be important that a management approach be implemented in a way that continues to be responsive to the values and objectives of Canadians. The manner of implementation will determine the effectiveness of any management approach, and the extent to which it reflects societal needs and concerns. It is through implementation that we will seek to build confidence.

The importance of implementation is reflected in the *NFWA*, which requires that our study address some specific aspects of implementation.

In Chapters 11 through 18, we address each of these legislated requirements in turn, and we expand our discussion to address additional considerations that we see as integral to the overall implementation plan.

Over the course of dialogues with the general public, Aboriginal Peoples and experts alike, many focused their comments on the features they believe should be part of the implementation plan that accompanies the management approach selected. Indeed, as we reported in Part Two, much of the common ground that we uncovered in our study relates to principles and expectations for how decisions will be taken, how citizens will be involved, and how any management approach will be implemented and monitored over time. In our discussion on implementation that follows, we were guided by the considerable advice and sharing of views we received the course of our study.

CHAPTER 11 /
FOUNDATION FOR IMPLEMENTATION

Nuclear Fuel Waste Act (*NFWA*) reference:
12. (6) Each proposed approach must include an implementation plan setting out, as a minimum,

(a) a description of activities;

(b) a timetable for carrying out the approach;

(c) the means that the waste management organization plans to use to avoid or minimize significant socio-economic effects on a community's way of life or on its social, cultural or economic aspirations; and

(d) a program for public consultation.

The *Nuclear Fuel Waste Act* (*NFWA*) sets out some specific elements of an implementation plan that are to be addressed for each option in our study.

With the decision by the federal government on a long-term management approach, we will embark on an implementation path spanning decades. During this period, implementation decisions proposed by NWMO could profoundly impact future generations. It is essential that the NWMO, in its continued stewardship of implementation in the years ahead, take great care that its processes support the most effective decision-making along the way.

Over the years, much has been invested in examining and understanding the management options presented by the different conceptual designs. Going forward, it will also be essential that we demonstrate a continued commitment to investing in process. The process by which a management approach is implemented will be an important determinant of the overall effectiveness of the approach and the extent to which it is, and continues to be, responsive to societal needs and concerns and in so doing, builds the confidence of Canadians.

Implementation plans cannot be detailed at this time.

- Plans must be discussed with the many communities of interest who will have important roles to play in overseeing and participating in implementation following a government decision on an approach. We expect to hear from a diversity of voices as we seek advice and receive direction on the design of the process, and the issues to be explored;

- Implementation plans will not be static. They must continue to evolve. The unprecedented nature of the time horizon brings with it a need for continuous learning, and a commitment to collaboratively define and periodically assess indicators of progress as a means of adapting to evolving conditions; and

- Specific timetables for implementation cannot be proposed at this time. The discussion that follows in Chapter 13 presents possible typical schedules that must be further discussed and defined as part of the collaboration and dialogue required to implement the government's decision, as part of the path ahead.

Implementation can be addressed in general terms at this time. There are many essential components that should be featured in implementing government's decision on a management approach.

Design of the decision-making process. With our study we have begun what will be an ongoing process that unfolds through the decision-making and implementation processes. There will be a continuum of engagement activities appropriate to support the decisions being taken at each step. We must communicate a clear decision-making path that includes accountability. We must provide assurance that commitments made will in fact be met, and that contingency plans are known and available should they be required. Safety for people and the environment must remain primary considerations as we proceed with implementation.

Aboriginal values and concerns remain a priority for the NWMO. We will continue to pursue relationships with Aboriginal People based on mutual trust, respect and integrity. We are committed to seeking an alignment between Aboriginal values and those reflected in our implementation plan.

We will build on the relationships that we have established. The three years of study led by the NWMO provide a starting point for the much longer-term outreach and engagement that will be the centerpiece of implementation. Through a diverse engagement program, we have sought to come to know and develop an ongoing dialogue with many communities of interest. Our engagement with the Canadian public and with Aboriginal Peoples is just beginning. As society moves through a lengthy decision-making process, the dialogue we have begun will continue and grow in the years to come.

We will seek to continue real dialogue. From the inception of our study, we have endeavoured to engage Canadians in a dialogue that permits a rich conversation through which to shape each step of our work. Many participants expressed support for the type of process that we have initiated to engage the public in the formulation of the recommendations. Public engagement must continue through the implementation phases. Although agreement between all participants may not always be forthcoming, effective dialogue facilitates a better understanding of different perspectives. Key is the creation of opportunities in which these important discussions may take place. This is an area in which process-related insights from Traditional Aboriginal Knowledge can be brought to bear to inform implementation.

However, engagement will become increasingly a local dialogue. As we move into the implementation phase, different interests will be identified by those who feel that they will be differentially impacted. We will encourage all parties with significant interest to participate so that we may understand their views and incorporate the broadest possible foundation of perspectives and knowledge into our implementation decisions. We want to understand concerns of citizens in regions and communities that are affected directly and indirectly. We also want such communities to become active players and problem solvers.

In order to support effective participation, we must ensure that the citizens and communities impacted by the selection of a site for the management facility are sufficiently resourced and informed to be equipped to participate in discussions and decision-making. Their participation must be based on an understanding of potential risks and the means to manage them. Communities affected by the facility must have opportunities for genuine involvement in the vicinity of any future facility. Communities should be informed, and participate in monitoring, as well as decision-making. Decision-making becomes increasingly more complex as more players demand an active role. Effective engagement is based on principles of openness, transparency, integrity and mutual respect, which imply a shared responsibility.

Societal considerations will assume greater significance in a site-selection process. We must continue to learn about, and adapt to, the requirements identified by communities of interest. Confidence in the technical aspects of a site is likely to be insufficient to provide the assurances that people seek in order to implement the project successfully. The management of used nuclear fuel involves both technical and social dimensions that cannot be separated.

We do not intend to site a facility without the support of the host community. Ultimately, quality of life, as perceived by the residents, will be a measure of whether or not we have recognized the impact of this project on their community. We must seek to design and implement our activities to foster positive change over the long term. Should there be adverse impacts, we must recognize the contributions and costs borne by the community through appropriate mitigation measures designed in collaboration with them.

Ensuring intellectual capacity to make decisions and to sustain operations will be key. Monitoring of emerging research and technical developments internationally will be important. Skills and capacities of workers must be sustained to support the safe operation of the facilities for the period of time for which institutional control is required.

In the chapters that follow, we address in turn, each of the required elements of the implementation plans as set out in the *NFWA*. We also address other elements that we believe are key components in implementing the management approaches that will play important roles in assuring procedural fairness, integrity and safety: institutions and governance (Chapter 12) and research and intellectual capacity (Chapter 16). Implementation issues associated with financial surety are addressed in Chapter 18.

In many areas of implementation, our recommendations would be similar for all four management approaches. In other areas, we identify where implementation approaches are set out differently, according to the option under review.

CHAPTER 12 /
INSTITUTIONS AND GOVERNANCE

There is an extensive governance framework in place that will oversee the long-term management of Canada's used nuclear fuel. This governance involves many participants who will participate in the ongoing decisions, implementation and operations related to the long-term management approach selected by the federal government.

As depicted in Figure 4-13, these organizations will together set the priorities and the responsibilities, manage implementation, and shape the spirit in which the many aspects of implementation will be carried out.

Following a decision by government on a management approach, activities associated with implementation of that decision will be overseen by governmental and regulatory bodies. We will be required to comply with all applicable legislative and regulatory requirements. The discussion in Chapter 12 summarizes some of the more significant governing legislation and highlights the key roles and responsibilities of the participants who will figure prominently in implementation.

For further discussion of the regulatory framework, see Appendix 11. Background Papers available at www.nwmo.ca/institutions, present a more comprehensive listing of statutes and other laws of general application that may also be relevant.

Figure 4-13 **Governance Framework for the Long-Term Management of Used Nuclear Fuel: Roles and Responsibilities**

Government of Canada

Responsible for:

- Making the decision on the long-term management approach for used nuclear fuel.
- Developing policy, regulating, and overseeing producers and owners of waste to ensure that they comply with legal requirements and meet their funding and operational responsibilities.

Natural Resources Canada

Responsible for:

- Recommending a management approach to the Government of Canada from the options in the NWMO study.
- Administering the *Nuclear Fuel Waste Act*, and monitoring the NWMO and the nuclear fuel waste owners to ensure compliance with the *NFWA*.
- Approving the funding formula and annual deposits to the trust funds, ensuring trust funds are established, and required deposits are made by the nuclear fuel waste owners.
- Reviewing NWMO's reports and making public statements.

Canadian Nuclear Safety Commission

Responsible for:

- Regulating the use of nuclear energy and nuclear materials to protect health, safety, security and the environment, and to respect related international obligations.
- Ensuring that Canada's international obligations are met, including safeguard agreements with the International Atomic Energy Agency (IAEA), and the Joint Convention on the Safety of Spent Fuel Management and the Safety of Radioactive Waste Management.
- Ensuring, prior to licensing, that environmental effects are carefully reviewed through environmental assessments, as required under the *Canadian Environmental Assessment Act*.
- Making determinations on licence applications brought forward by the NWMO for siting, constructing, operating, modifying and decommissioning the long-term management facilities.
- Undertaking ongoing compliance and enforcement of statutory requirements and current licence requirements and conditions, taking enforcement actions on incidents of non-compliance.

Transport Canada

Responsible for:

- Establising and enforcing requirements to promote public safety during the transport of dangerous goods including radioactive material (in coordination with the CNSC).
- Approving Emergency Response Assistance Plans prior to transport.

Canadian Environmental Assessment Agency

Responsible for:

- Administering the *Canadian Environmental Assessment Act* with which the CNSC must comply before proceeding with each licence application from the NWMO.

Provincial Governments/Regulators

Responsible for:

- Shareholders/owner accountabilities for provincial nuclear power corporations.
- Enforcing provincial statutes that contribute to the regulatory framework that the NWMO must meet.

Nuclear Fuel Waste Owners

Responsible for:

- Establishing trust funds to finance the implementation of the long-term management approach selected by government.
- Establishing and maintaining a Nuclear Waste Management Organization.

Currently Canada's owners of used nuclear fuel are: Ontario Power Generation Inc. (owns approximately 90 percent of the used fuel), Hydro-Québec, NB Power Nuclear, and Atomic Energy of Canada Limited.

Nuclear Waste Management Organization (NWMO)

Responsible for:

- Preparing the study of long-term management options.
- Consulting with the general public and Aboriginal Peoples.
- Implementing the management approach selected by Government, carrying out the associated managerial, financial and operational activities.
- Reporting regularly to the Minister of Natural Resources Canada and the public.

Figure 4-13 (cont'd) **Governance Framework for the Long-Term Management of Used Nuclear Fuel: Roles and Responsibilities**

Advisory Council to the NWMO

Responsible for:

- Examining and providing written comments on the NWMO's study of management approaches submitted to the Minister of Natural Resources Canada.
- Examining and providing written comments in NWMO's triennial reports to the Minister, on the NWMO's activities, strategic plans, budget forecasts and public consultations.
- Providing ongoing guidance to the NWMO.

Communities

Responsible for:

- Monitoring and reporting community conditions and, in particular, any changes that result from the NWMO activities.
- Addressing any aspects of nuclear waste management that have been agreed upon through discussions with the NWMO and government.
- Administering applicable municipal permitting and taxation.
- Overseeing the community's role in emergency preparedness and response.

Aboriginal Institutions

Responsible for:

- Monitoring and reporting conditions within traditional territories and, in particular, any changes that result from the NWMO activities.
- Addressing any aspects of nuclear waste management that have been agreed upon through discussions with the NWMO and government.
- Overseeing the community's role in emergency preparedness and response.

12.1 / The Government of Canada

The federal government has an important policy role to play in the long-term management of used nuclear fuel, in cooperation with the provinces and the nuclear waste producers. The government is responsible for developing policy and overseeing the producers and owners of used nuclear fuel in order that they meet their operational and funding responsibilities in accordance with the approved long-term waste management plans. The government has put in place policies, legislation and regulations to provide direction and oversight for radioactive waste management in Canada.

In July 1996, the federal government announced its Policy Framework for Radioactive Waste. This Framework set out principles to govern the institutional and financial arrangements for radioactive waste management in Canada. It defines the role of government and waste producers:

- The federal government will ensure that radioactive waste disposal is carried out in a safe, environmentally sound, comprehensive, cost-effective and integrated manner;

- The federal government has the responsibility to develop policy, to regulate, and to oversee producers and owners to ensure that they comply with legal requirements and meet their funding and operational responsibilities in accordance with approved waste disposal plans; and

- The waste producers and owners are responsible, in accordance with the principle of "polluter pays," for the funding, organization, management and operation of disposal and other facilities required for their wastes. This recognizes that arrangements may be different for nuclear fuel waste, low-level radioactive waste and uranium mine and mill tailings.

Consistent with the Policy Framework, the Canadian Parliament passed the *Nuclear Fuel Waste Act* (*NFWA*) in 2002. The *NFWA* assigns roles and responsibilities for the long-term management of used nuclear fuel consistent with the government's Policy Framework for Radioactive Waste Management.

Under the *NFWA*, the federal government holds decision-making authority on the management approach selected for used nuclear fuel. The government will make a decision on the management of used nuclear fuel that is based on a comprehensive, integrated and economically sound approach for Canada.

12.2 / Natural Resources Canada

The federal Minister of Natural Resources Canada is responsible for the administration of the *NFWA*.

In administering this legislation, Natural Resources Canada has an important role in overseeing the long-term management of used nuclear fuel.

The Minister of Natural Resources Canada will receive our study, that is to be submitted by November 15, 2005. In this study, the Minister will receive the comments from the Advisory Council to the NWMO, and a summary of comments from our engagement with the general public and Aboriginal Peoples.

Upon receipt of our study, Natural Resources Canada will initiate an inter-departmental review to invite comments from various departments, as well as the Canadian Nuclear Safety Commission. It is upon the recommendation of the Minister of Natural Resources Canada that the government will make a decision on the management approach from the proposals of the NWMO.

After the government decision, the Minister's oversight continues, under the various requirements of the *NFWA*.

Outlined below, are examples of legislated provisions in the *NFWA* that make explicit the oversight of the Minister of Natural Resources Canada. Chapter 18 addresses in more detail, the Minister's role in reviewing and approving financial provisions for the management approach.

Nuclear Fuel Waste Act (*NFWA*) reference:
12. (1) Within three years after the coming into force of this Act, the waste management organization shall submit to the Minister a study setting out:

(a) its proposed approaches for the management of nuclear fuel waste, along with the comments of the Advisory Council on those approaches; and

(b) its recommendation as to which of its proposed approaches should be adopted.

14. (1) The Minister may engage in such consultations with the general public on the approaches set out in the study as the Minister considers necessary.

14. (2) If the Minister is of the opinion that the study fails in a significant way to meet the requirements of sections 12 and 13, the Minister shall direct the waste management organization to revise the relevant portions of it and submit the revised study to the Minister within the period that the Minister specifies.

15. The Governor in Council, on the recommendation of the Minister, shall select one of the approaches for the management of nuclear fuel waste from among those set out in the study, and the decision of the Governor in Council shall be published in the Canada Gazette.

16. (1) The waste management organization shall, within three months after the end of each fiscal year of the organization, submit to the Minister a report of its activities for that fiscal year.

16. (3) The formula referred to in paragraph (2)(d) and the amount of each deposit referred to in paragraph (2)(e) are subject to the approval of the Minister when proposed in:

(a) the first annual report after the date of a decision of the Governor in Council under section 15 or subsection 20(5); and

(b) the first annual report after the issuance, under section 24 of the Nuclear Safety and Control Act, of a construction or operating licence for an activity to implement the approach that the Governor in Council selects under section 15 or approves under subsection 20(5).

16. (4) If the Minister

(a) is not satisfied that the formula referred to in paragraph (2)(d) will provide sufficient funds to implement the approach that the Governor in Council selects under section 15 or approves under subsection 20(5), or

(b) is not satisfied that the amount of each deposit referred to in paragraph (2)(e) is consistent with the formula referred to in paragraph (2)(d),

the Minister shall refuse to give the approval referred to in subsection (3) and shall direct the waste management organization to revise the relevant portions of the annual report and submit the revised annual report to the Minster within 30 days.

19. The Minister shall, within 90 days after receiving a report, issue a public statement regarding the report.

19. (1) The Minister shall cause a copy of each report to be laid before each House of Parliament within the first fifteen sitting days of that House after the Minister has received the report.

23. (1) The waste management organization shall provide the Minister, within three months after the end of each fiscal year of the organization, with financial statements audited at its own expense by an independent auditor.

(2) Every financial institution that holds a trust fund shall provide the Minister and the waste management organization, within three months after the end of each fiscal year of the trust fund, with financial statements relating to that trust fund, audited at its own expense by an independent auditor.

24. The waste management organization shall make available to the public

(a) the study, reports and financial statements that it is required to submit to the Minister under this Act, simultaneously with submitting them to the Minister; and

(b) financial statements provided to the waste management organization under subsection 23(2) as soon as practicable.

12.3 / Canadian Nuclear Safety Commission

Any option chosen for the long-term management of used nuclear fuel will have to meet the regulatory requirements governing such facilities.

The Canadian Nuclear Safety Commission (CNSC) is the lead federal organization overseeing operations by the nuclear industry in Canada. The CNSC is an independent regulatory agency of the federal government, responsible for regulating the use of nuclear energy and nuclear materials to protect the health, safety, and security of Canadians, to protect the environment, and to ensure that Canada's commitments on the peaceful use of nuclear energy are respected.

The CNSC, operating within the mandate and authority of the *Nuclear Safety and Control Act*, regulates all activities relating to nuclear materials, equipment and processes within Canada. The requirements of the *NSCA* , as administered and applied by the CNSC, will oblige the NWMO to obtain licences for the site preparation, construction, operation, modification, decommissioning, and where applicable, abandonment of disposal/storage facilities.

The CNSC's regulatory regime covers the entire nuclear substance lifecycle, from production, use, to final disposition of any nuclear substances.

Of particular significance is the CNSC compliance program. Once a licence is issued, the licensed activities are monitored by the CNSC to ensure compliance with the regulatory requirements. Non-compliance is corrected using a set of graduated enforcement actions that range from verbal discussions and written notices to legal prosecution and revocation of licence.

The CNSC has established principles that it will take into account in making regulatory decisions concerning the long-term management of used nuclear fuel. The CNSC has issued a Draft Regulatory Guide, G-320, for public comment, which sets out typical ways to assess impacts that the long-term waste management may have on the environment and on the health and safety of people in the long term. It is intended to assist licensees and applicants in assessing the long-term safety of storage and disposal of radioactive waste. Details are set out in Appendix 11.

In operating a nuclear waste repository, we will be required to demonstrate that it is in accord with the regulations made under the *NSCA*. The NWMO will also be required to demonstrate compliance with the conditions of its licence(s). For centralized options, we will be required to use a package design that will be certified by the CNSC, and obtain a licence to transport fuel waste materials to the centralized repository.

The CNSC regulates the safe transport of nuclear substances under the *NSCA* in coordination with Transport Canada, under the *Transportation of Dangerous Goods Act*. As part of this process, the CNSC establishes package design requirements, reviews safety cases, and ensures the physical security of the materials and performs compliance inspections. Any shipment(s) of spent fuel will require the NWMO (licensee, transporter) to file a transport security plan with the CNSC to ensure that the proposed security measures for any spent fuel shipments are commensurate with any credible threat at the time of shipment(s).

In meeting its obligations under the *Canadian Environmental Assessment Act*, the CNSC is required to determine whether an environmental assessment must be performed to assess the potential for significant environmental impacts before the CNSC exercises its regulatory authority in issuing licences. It is anticipated that the CNSC would require the NWMO to undertake an Environmental Assessment prior to making a decision on an application for a licence for site preparation, construction, modification, decommissioning or abandonment of a nuclear waste facility. The *Canadian Environmental Assessment Act* is the basis for the federal practice of environmental assessment to ensure that the environmental effects of projects involving the federal government are considered early in the project's planning stages. The Act is administered by the Canadian Environmental Assessment Agency. For further details concerning the relationship between the *Canadian Environmental Assessment Act* and the CNSC licensing process, see background paper 7-9. (www.nwmo.ca/cnsclicensing)

The CNSC, in applying the *NSCA* to determine the merits of any licence application within its purview, and thereby issue, renew, suspend, amend, revoke or replace a licence, will make determinations on whether or not an applicant has also fulfilled the legislative and regulatory obligations of the *Nuclear Liability Act*, the *Canadian Environmental Protection Act*, the *Canada Transportation Act* and its regulations, and other acts and regulations it deems appropriate. The CNSC works with provincial, national and international agencies in harmonizing the regulation of radioactive waste management in Canada.

The CNSC usually issues licences for short periods of time. These licences must be renewed as part of the ongoing regulatory process. Licensing decisions are revisited with each renewal application. In considering each licence application, the CNSC takes into account the history of performance and compliance of the licensee, and the design and implementation of the licensee's programs in the areas of operations, quality assurance, radiation protection, environmental protection, non-radiological health and safety, emergency preparedness, nuclear security, safeguards and public information. This process continues until a licence to abandon is granted. Each application triggers a determination of the need for an environmental assessment under CEAA. The potential long-term impacts from the used fuel need to be taken into account at each licence decision.

The CNSC may require that operators of nuclear facilities provide financial guarantees to ensure that operations will take place in a responsible and orderly manner. In the event that the waste owners are unable to pay and adequate financial guarantees are not in place, responsibility would rest with the federal and/or provincial governments, as managers of last resort.

The CNSC requires that all nuclear facilities have a decommissioning plan in place. The plan identifies the end-state of the facility and site, identifies the activities to achieve that end state, and includes an assessment of the potential environmental effects of the proposed decommissioning program. This decommissioning plan forms the basis for the financial guarantee, which is required to ensure that there will be funds available to implement the decommissioning plan and to prevent any financial burden on future generations. Future financial burden could arise from the need for institutional controls and the long-term care and maintenance of the wastes.

International Responsibilities

The CNSC is responsible for implementing Canada's international nuclear non-proliferation, safeguards and security obligations in collaboration with Foreign Affairs Canada.

The cornerstone of the international nuclear non-proliferation regime is the Treaty on the *Non-Proliferation of Nuclear Weapons* (NPT). The NPT establishes commitments to prevent the spread of nuclear weapons, promote cooperation in the peaceful uses of nuclear energy, and achieve nuclear disarmament. Canada is an original signatory to the NPT and has centered its own nuclear non-proliferation policy on the treaty's provisions.

Canada has in place a comprehensive safeguards agreement with the International Atomic Energy Agency (IAEA) pursuant to the NPT. Safeguards require accurate accounting of nuclear material and inspection activities which include various technical measures to provide assurance to the IAEA that the sensitive material remains in place. The safeguards agreement gives the IAEA the right and obligation to monitor Canada's nuclear-related activities and to verify nuclear material inventories and flows in Canada. The CNSC is responsible for implementing the Canada/IAEA safeguards agreement and protocols. Through its regulatory process, the CNSC performs compliance and auditing activities to ensure that all relevant licensees have in place safeguards, policies and procedures to comply with these international commitments. Safeguards are intended to provide assurance to the international community that Canada is not diverting material for weapons or other purposes. These are serious obligations and non-cooperation has significant repercussions.

The NWMO, by operating under the jurisdiction of the CNSC, will also be required to manage its operations in accord with the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management. Under the Joint Convention, Canada must demonstrate that it is meeting international commitments to manage radioactive waste and spent fuel safely.

12.4 / Transport Canada

Transport Canada promotes public safety during the transportation of dangerous goods. The department is responsible for regulating all dangerous goods that are transported in Canada, including Class 7 materials (radioactive materials). The division of responsibility for the regulation of transport of radioactive material is shared between Transport Canada and the Canadian Nuclear Safety Commission. Transport Canada and the CNSC both have primarily adopted IAEA *Regulations for the Safe Transport of Radioactive Material*.

For Class 7 shipments Transport Canada is primarily responsible for:

- Establishing and enforcing any transportation requirements for carriers, vehicles or other conveyances except for the radiation protection program for the carriers;
- Establishing requirements and undertaking compliance inspections for transportation aspects such as training, classification, documentation, marking, labeling and placarding, emergency response planning and notification of releases and incident reporting;
- Setting the requirements of Emergency Response Assistance Plan and reviewing and approving them; and
- Undertaking compliance inspections primarily to ensure that the *Transport of Dangerous Goods Regulations* are met.

Transport Canada enforces the requirement for detailed Emergency Response Assistance Plans to be in place prior to the transport of dangerous goods such as radioactive waste. Prior to transporting any nuclear fuel, the NWMO would be required to complete and receive an approval from Transport Canada of an Emergency Response Plan that met the requirements of the department, providing details on the contents, containers, transport routes and emergency response plans in place.

Transport Canada plays a key role in the response to emergencies and crises when they occur. In the event of an incident involving dangerous goods, the Canadian Transport Emergency Centre (CANUTEC), operated by Transport Canada, can assist emergency response personnel. Canadian emergency preparedness necessarily includes all levels of government, agencies and non-governmental organizations.

The CNSC is the prime agency of the federal government entrusted with regulating all activities related to the use of nuclear energy and nuclear substances, including the packaging and transport of nuclear substances. The CNSC is primarily responsible for:

- The packaging aspects such as setting the package design requirements and reviewing the safety case;
- Establishing and enforcing the radiation protection program for the carriers;
- Investigating in the event of a dangerous occurrence;
- Issuing licences for shipments that require a licence to transport in accordance with the *Packaging and Transport of Nuclear Substances Regulations*;
- All aspects of physical security measures of nuclear substances and prescribed equipment against sabotage or theft for all modes and phases of transport; and
- Compliance inspections to ensure that the *Transport of Dangerous Goods Regulations* and the *Packaging and Transport of Nuclear Substances Regulations* requirements are met.

12.5 / Provincial Governments and Regulators

There may be some aspects of siting, construction and/or operation of a central used fuel management facility that may be determined to be governed by provincial legislation. The legislative areas listed below may be relevant. Note that in many cases provincial legislation adopts the procedures and requirements of federal acts and regulations. In some instances, the provincial and federal governments have adopted harmonized procedures.

- Transportation: Most all provinces and territories include nuclear substances in legislation and regulations addressing the transportation of dangerous goods within that province or territory;

- Emergency preparedness: Responsibilities for nuclear emergency preparedness fall to several levels of government. In particular, CNSC has requirements in its Class 1 Nuclear Facilities Regulations and Regulatory Guide G-225. Provincial governments are responsible for protecting public health and safety, property and the environment within their borders. Provincial emergency preparedness legislation often requires that a plan be formulated to address off-site responses to emergencies at nuclear facilities (e.g., *Ontario Emergency Management Act*); and

- Environmental assessment and approvals: Provincial legislation requiring the assessment of potential environmental effects of an activity, plan or program may apply to some aspects of our work. For example, in Québec, the *BAPE – Bureau d'audiences publiques sur l'environnement* (public environmental hearing board) which mainly oversees the provincial environmental assessment process, has a responsibility to inform and consult the population about questions relating to the quality of the environment or certain projects which could significantly affect the environment and cause public concern.

In addition, legislation governing endangered species; environmental protection; heritage protection or preservation; water resources protection; occupational health and safety; and/or labour relations may be determined to be relevant. Municipalities, which derive their authority from provincial legislation, may have requirements that may also be relevant.

Appendix 11 provides more detail on the Canadian regulatory framework relevant to the management of used nuclear fuel.

12.6 / Nuclear Fuel Waste Owners

Nuclear Fuel Waste Act (*NFWA*) reference:

6. (1) The nuclear energy corporations shall establish a corporation, in this Act referred to as the waste management organization...

6. (2) Once the waste management organization has been established, every nuclear energy corporation shall become and remain a member or shareholder of it.

9. (1) Each nuclear energy corporation and Atomic Energy of Canada Limited shall maintain in Canada, either individually or jointly with one or more of the other nuclear energy corporations or Atomic Energy of Canada Limited, one trust fund with a financial institution incorporated or formed by or under an Act of Parliament or of the legislature of a province, except, in the case of a nuclear energy corporation, a financial institution in relation to which the nuclear energy corporation beneficially owns, directly or indirectly, more than ten percent of the outstanding shares of any given class of shares.

The *NFWA* formally assigns specific responsibilities to the waste owners.

It requires that the nuclear energy corporations establish a nuclear waste management organization. The nuclear energy corporations are the corporations that own nuclear fuel resulting from production of electricity by means of a commercial nuclear reactor. These corporations, which include

Ontario Power Generation Inc., NB Power Nuclear and Hydro-Québec, must remain members or shareholders of the organization.

This governance model is similar to those in Finland and Sweden, where the nuclear waste owners have the responsibility to establish and fund the implementing organization with responsibility for used nuclear fuel management.

Under the *NFWA*, the major owners of nuclear fuel waste – the nuclear corporations and AECL – will finance the long-term management approach selected by government, including costs of designing and siting the approved approach, implementing and finally, decommissioning the facilities. The *NFWA* requires a specific guarantee in the form of trust funds into which nuclear energy corporations and AECL deposit money each year for the long-term management of used nuclear fuel. Money in the funds can only be withdrawn by the NWMO, and only after a construction or operating licence for a long-term management facility has been granted by the CNSC. To date, a total of $770 million has been deposited into the trust funds. The financial obligations of the waste owners, assigned by the *NFWA*, are elaborated on in Chapter 18.

12.7 / Nuclear Waste Management Organization (NWMO)

Nuclear Fuel Waste Act (*NFWA*) reference:
6. (1) The nuclear energy corporations shall establish a corporation, in this Act referred to as the waste management organization, whose purpose under this Act is to do the following on a non-profit basis:

(a) propose to the Government of Canada approaches for the management of nuclear fuel waste; and

(b) implement the approach that is selected under section 15 or is approved under subsection 20(5).

6. (3) For all purposes the waste management organization is not an agent of Her Majesty in right of Canada.

12. (1) Within three years after the coming into force of this Act, the waste management organization shall submit to the Minister a study setting out

(a) its proposed approaches for the management of nuclear fuel waste, along with the comments of the Advisory Council on those approaches; and

(b) its recommendation as to which of its proposed approaches should be adopted.

12. (7) The waste management organization shall consult the general public, and in particular aboriginal peoples, on each of the proposed approaches. The study must include a summary of the comments received by the waste management organization as a result of those consultations.

Mandate

The NWMO has been created as a corporation that will continue to exist to fulfill the ongoing mandate as required under the *NFWA*.

- The first phase of the legislated mandate included conducting the study on management approaches and proposing a recommendation to the government; and
- After a decision is made by the Government of Canada, that specifies a particular management approach for the storage/disposal of all Canadian spent nuclear fuel, we will then proceed to implement the management approach. We will be responsible for managing and coordinating the full range of activities related to the long-term management of used nuclear fuel.

The enduring nature of the NWMO as an organization will enable the insights and relationships developed in the course of the three-year study of options to be carried forward and built upon in the succeeding years of implementation. The centerpiece for the next phase of our mandate will be the relationships we established and the insights and lessons of the past three years.

The vision, mission and values that have guided us in our study of management approaches will continue to guide the organization as it moves into its role as an implementing organization. We should be held accountable to our values and our responsibilities. In order to succeed in implementation, we will need to be an accountable organization in which Canadians can have confidence, and we must have a track record that can be trusted.

A component of establishing integrity as an organization has to do with ensuring the organization is equipped with the resources and skills necessary to continue in the next phases. The size and composition of the NWMO must adapt over time as appropriate to fulfill subsequent phases of its mandate. Following a government decision on an approach, we must address the skills and competencies required for the organization to transition into the next phase of its mandate.

During implementation, we are directed and governed by the articles set out in the *NFWA*. When we move into the implementation phase of its mandate, we will also be subject to a number of federal, provincial and international acts and regulations.

Each of these operations will require that we be in accord with various acts of law and regulations. The NWMO is established as a corporation that will operate on a non-profit basis.

Governance

Consistent with the governance structure set out in the *NFWA*, the nuclear energy corporations – Ontario Power Generation Inc., NB Power Nuclear, and Hydro-Québec – established the NWMO in 2002.

The Board of Directors is responsible for oversight of the corporation and taking a leadership role in the development of the corporation's strategic direction. The Board of Directors has directed the NWMO to make public the minutes from its board meetings to provide transparency in its operations.

To formalize their obligations to establish the NWMO, the three founding member corporations clarified the roles and responsibilities of the Member corporations in furthering those objectives. Members agreed upon provisions for cost-sharing our annual operating budget up to an annual maximum. These provisions will ensure that we have a secure and ongoing source of funds with which to carry out our activities and operations.

The Board of Directors appoints a President and CEO, who is accountable for the operation of the company. The President is responsible for the organization's planning, program design, direction and day-to-day operations.

It is under the governance of the Board of Directors, that we will continue to carry out the managerial, financial and operational activities to implement the long-term management of nuclear fuel waste. The NWMO Board seeks to ensure that the study is conducted in the full spirit of the *NFWA*, and that the organization is equipped to fulfill its ongoing role as envisaged by the legislation. While our current focus is completion of the study, the Board is mindful of our post-study mandate to implement the government's decision, and has endeavoured to establish the foundation for the NWMO to transition into the next phase of its legislated mandate. As part of the planning for the NWMO to assume the second phase of its legislated mandate, that of implementing government's decision, the Board is addressing the underlying governance and funding requirements.

In planning for the next phase of our mandate, the Board of Directors is reviewing its composition. As required by the *NFWA*, the three nuclear corporations – Ontario Power Generation Inc., Hydro-Québec and NB Power Nuclear – are all represented on the NWMO membership.

The Board of Directors believes, however, that expanding the Board membership to include independent directors should be considered, to help address the expressed public concern with regard to a Board that is exclusively industry-based and to reflect evolving good governance practices.

Reporting

The NWMO has extensive reporting requirements to the Minister of Natural Resources Canada. These reporting requirements, outlined in detail in the *NFWA*, reflect the ongoing oversight role of the federal government that will remain in effect through subsequent phases of implementation and operation of the long-term used fuel management approach. Annual and triennial reporting requirements to the Minister, and to the Canadian public, provide important measures of ongoing accountability of the NWMO.

<table>
<tr><td>Nuclear Fuel Waste Act (NWFA) References:</td><td></td></tr>
<tr><td>ANNUAL REPORTS</td><td>TRIENNIAL REPORTS</td></tr>
<tr><td>16. (1) The waste management organization shall, within three months after the end of each fiscal year of the organization, submit to the Minister a report of its activities for that fiscal year.

16. (2) Each annual report after the date of the decision of the Governor in Council under section 15 must include:

(a) the form and amount of any financial guarantees that have been provided during that fiscal year by the nuclear energy corporations and Atomic Energy of Canada Limited under the Nuclear Safety and Control Act and relate to implementing the approach that the Governor in Council selects under section 15 or approves under subsection 20(5);

(b) the updated estimated total cost of the management of nuclear fuel waste;

(c) the budget forecast for the next fiscal year;

(d) the proposed formula for the next fiscal year to calculate the amount required to finance the management of nuclear fuel waste and an explanation of the assumptions behind each term of the formula; and

(e) the amount of the deposit required to be paid during the next fiscal year by each of the nuclear energy corporations and Atomic Energy of Canada Limited, and the rationale by which those respective amounts were arrived at.

17. (1) Each nuclear energy corporation and Atomic Energy of Canada Limited shall, either directly or through a third party, deposit to its trust fund maintained under subsection 9(1) its respective deposit specified in the annual report

(a) if the Minister’s approval under subsection 16(3) is not required, within 30 days after the annual report is submitted to the Minister under subsection 16(1); or

(b) if the Minister’s approval under subsection 16(3) is required, within 30 days after the date of that approval.

17. (2) Notwithstanding subsection (1), the Governor in Council may, on request by a nuclear energy corporation made before the expiration of the 30 day period referred to in that subsection, authorize the nuclear energy corporation to defer by one year all or part of its deposit required by that subsection, if the Governor in Council is of the opinion that the public interest requires that the money be used instead to repair the damage caused by an event that is not attributable to the corporation and is extraordinary, unforeseen and irresistible.</td><td>18. The annual report of the waste management organization for its third fiscal year after the fiscal year in which a decision is made by the Governor in Council under section 15, and for every third fiscal year after that, in this Act called the “triennial report”, must include

(a) a summary of its activities respecting the management of nuclear fuel waste during the last three fiscal years, including an analysis of any significant socio-economic effects of those activities on a community’s way of life or on its social, cultural or economic aspirations;

(b) its strategic plan for the next five fiscal years to implement the approach that the Governor in Council selects under section 15 or approves under subsection 20(5);

(c) its budget forecast for the next five fiscal years to implement the strategic plan;

(d) the results of its public consultations held during the last three fiscal years with respect to the matters set out in paragraphs (a) and (b); and

(e) the comments of the Advisory Council on the matters referred to in paragraphs (a) to (d).</td></tr>
<tr><td colspan="2">OTHER REPORTING</td></tr>
<tr><td colspan="2">22. (1) The waste management organization, every nuclear energy corporation and Atomic Energy of Canada Limited, as well as every financial institution that holds a trust fund, shall keep, at its place of business in Canada, records, books of account and other documents for at least six years after the end of the fiscal year to which they relate, in such form and containing such information as will enable the verification of the accuracy and completeness of the information that is required to be submitted or provided to the Minister under this Act.
(2) No person shall make false entry or fail to make an entry, in a record, book of account or other document required to be kept under subsection (1).

23. (1) The waste management organization shall provide the Minister, within three months after the end of each fiscal year of the organization, with financial statements audited at its own expense by an independent auditor.
(2) Every financial institution that holds a trust fund shall provide the Minister and the waste management organization, within three months after the end of each fiscal year of the trust fund, with financial statements relating to that trust fund, audited at its own expense by an independent auditor.

24. The waste management organization shall make available to the public
(a) the study, reports and financial statements that it is required to submit to the Minister under this Act, simultaneously with submitting them to the Minister; and
(b) financial statements provided to the waste management organization under subsection 23(2) as soon as practicable.</td></tr>
</table>

Advisory Council

Nuclear Fuel Waste Act (*NFWA*) reference:
8. (1) The waste management organization shall create an Advisory Council, which shall

(a) examine the study referred to in subsection 12(1) and the triennial reports referred to in section 18 that are to be submitted to the Minister; and

(b) give written comments on that study and those reports to the waste management organization.

8. (2) The members of the Advisory Council shall be appointed by the governing body of the waste management organization. The governing body shall make all reasonable efforts to ensure that the Advisory Council's membership

(a) reflects a broad range of scientific and technical disciplines related to the management of nuclear fuel waste;

(b) reflects expertise, in matters of nuclear energy,
(i) in public affairs, and
(ii) as needed, in other social sciences;

(b.1) reflects expertise in traditional aboriginal knowledge; and

(c) includes representatives nominated by local and regional governments and aboriginal organizations that are affected because their economic region is specified for the approach that the Governor in Council selects under section 15 or approves under subsection 20(5).

The *NFWA* requires the governing body of the waste management organization to appoint an Advisory Council. The *NFWA* assigned the Council specific responsibilities, and provides direction on the membership of the Advisory Council.

The NWMO Board of Directors appointed the Advisory Council in Fall 2002, consistent with the legislation. There are presently nine Advisory Council member that were appointed for four-year terms. Advisory Council members are listed in Appendix 1.

The independent comments of the Advisory Council on our study and the management approaches, required by the *NFWA*, will be included in our final study submitted to government in November 2005. The Advisory Council has released its statement as to how it intends to discharge that legislated mandate. This statement is provided in Part Five.

The legislative direction concerning Council membership will continue to be upheld as we move into future phases of our mandate. Within the parameters of the *NFWA*, membership will change over time as the project proceeds from a study on management options, to a concept chosen by government, and then, to a site-specific project in a known location and region.

Once an economic region is identified for implementing the approach selected by the government, the act requires the Advisory Council to include representatives nominated by those local and regional governments and Aboriginal organizations.

The Advisory Council has an ongoing responsibility to examine and to provide written comments on the triennial reports that we must submit to the Minister of Natural Resources Canada.

12.8 / Communities

Discussion of the definition of "community" is found in Chapter 15. There are legal definitions of local government designations such as cities, municipalities, municipal districts, regional districts, counties, towns, townships, villages, parishes, hamlets and indian reserves. In reality, both place-based communities and interest-based communities play a role in our work. In both cases, communities are responsible for:

- Monitoring and reporting community conditions and in particular, any changes that result from our activities;
- Addressing any aspects of used nuclear fuel management that have been agreed upon through discussions with the NWMO and government;
- Applicable municipal permitting and taxation; and
- Their particular role in emergency preparedness and response.

The NWMO has a responsibility to work with the various communities to negotiate effective ways and means for communities to assume and discharge any responsibilities that arise related to the long-term management of used nuclear fuel. Over the past decade, a number of innovative institutional arrangements have been developed to facilitate the development of such community capacity. A number of examples are described in Chapter 15. Many of these involve some kind of formal agreement between the community or elements of the community and a project lead, like the NWMO. Any implementation plan would be developed collaboratively with communities.

12.9 / Aboriginal Organizations

The NWMO also has a responsibility to work with Aboriginal organizations and communities to negotiate effective ways and means for Aboriginal Peoples to assume and discharge any responsibilities that arise related to the long-term management of used nuclear fuel. Such responsibilities would include:

- Monitoring and reporting conditions within traditional territories and in particular, any changes that result from NWMO activities;
- Addressing any aspects of used nuclear fuel management that have been agreed upon through discussions with the NWMO and government;
- Implementing any procedures and protocols that are part of the evolving structures of self-government; and
- Any agreed upon Aboriginal role in emergency preparedness and response.

A number of the innovative institutional arrangements that are described in Chapter 15 arise from Aboriginal experience. It will be essential to develop any implementation plan for used fuel management in collaboration with Aboriginal Peoples.

CHAPTER 13 / DESCRIPTION OF ACTIVITIES AND TIMETABLES

Nuclear Fuel Waste Act (*NFWA*) reference:
12. (6) Each proposed approach must include an implementation plan setting out, as a minimum,

(a) a description of activities;

(b) a timetable for carrying out the approach;

(c) the means that the waste management organization plans to use to avoid or minimize significant socio-economic effects on a community's way of life or on its social, cultural or economic aspirations; and

(d) a program for public consultation.

Activities and possible timetables are presented in the sections that follow for each of the four management approaches, to meet the legislated requirement that we address these issues.

It is important to note that the timetables outlined below are put forward as possible typical implementation schedules only. They provide an indication of a representative schedule for implementation of each approach under study.

The timetables below present possible paths forward for implementation; other timelines may also be appropriate for implementation of each approach. References to implementation timelines in the sections below should be considered as possible timelines, illustrative of the time required to proceed through the various stages of siting, regulatory approvals and construction. The timelines were the basis of the cost estimates prepared for each management approach. They have not been optimized nor do they necessarily reflect the most appropriate schedules when technical and social considerations are taken into account. These illustrative timelines should not be considered as the definitive implementation timetables, which would need to be defined following a decision on a management approach by the federal government.

It is important to note that the regulatory regime will require licences to be obtained throughout various stages in the lifecycle of a waste management facility including site preparation, construction, operation, modification and decommissioning. As well an emergency plan will have to be submitted and approved. Canadian standards and regulations will continue to evolve taking into account requirements for international safeguards.

13.1 / Option 1: Deep Geological Disposal in the Canadian Shield

This section presents an estimated timetable for the implementation activities anticipated to site, design, construct, operate, monitor, decommission and close a deep geologic repository for the placement of used fuel. The schedule and assumptions are based on the conceptual design and cost estimating reports prepared by consultants for the Joint Waste Owners. (See conceptual design reports at www.ca/conceptualdesigns).

The deep geologic repository program is often divided into two distinct periods: the preclosure period and the postclosure period. The preclosure period (Year 1 – 154) includes all activities from siting through to decommissioning and closure of all facilities related to the repository. After Year 154, it is assumed that the repository will be sealed and the site closed, and that regulatory approval will be received to abandon the site. The phases of the preclosure period are presented in Figure 4-14 and described in detail below.

Siting Phase

The siting phase covers the time period in which a suitable location for a deep geologic repository in the Canadian Shield is being sought. It begins after a formal decision is made to start the process of finding a suitable site and would end when regulatory approval is received to construct the facility at the preferred site (estimated to be Years 1 – 18).

The siting phase would involve developing a siting process that would include both thorough public dialogue and engagement, and technical assessments on the basis of site characteristics. The acceptability of a site will be determined on the outcome of this siting process. The major components of the siting process will include initial public engagement, discussions and hearings, development and application of site screening criteria, an Environmental Assessment and the preparation of licence applications. Each of these major components necessarily includes both public involvement/participation and technical assessment and analysis.

The outcome of these public engagement activities would be coupled with the initial site characterization and screening to gain consensus toward selecting a preferred site. Site characterization activities during the siting phase would involve an iterative process of investigation beginning with non-invasive surface-based feasibility studies at perhaps three candidate areas followed by more detailed surface and underground characterization via borehole drilling at select candidate sites and the final preferred site. These activities would provide an understanding of site-specific geosphere and biosphere conditions necessary to assess and communicate possible site suitability to host a deep geologic repository.

Figure 4-14 Overall Work Schedule for Deep Geological Disposal in the Canadian Shield

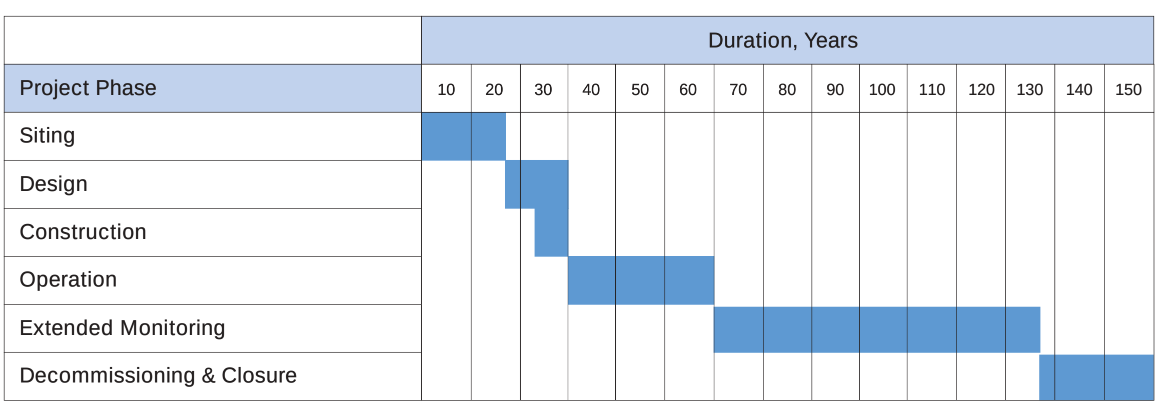


Figure 4-15 **Activity Flowchart for Deep Geological Disposal in the Canadian Shield**

YEAR 1

Government Decision to proceed with Deep Geological Disposal in the Canadian Shield

↓

Develop an **Engagement Program** collaboratively with potential site, transportation route, aboriginal and non-aboriginal communities; incorporate insights from all NWMO work.

↓

Implement the **Engagement Program**, initiating the **Siting Process** to select preferred site (stakeholder consultations, feasibility studies, site characterization); **Design and Safety Assessment** activities in parallel

YEAR 11

↓

Conduct further site characterization and prepare **design** for Underground Characterization Facility and **preliminary design** of deep geologic repository.

YEAR 16

↓

Perform an **Environmental Assessment** for the preferred site (including public engagement and safety analysis); obtain a **Site Preparation Licence** and a **Construction Licence** for the Underground Characterization Facility, the deep geologic repository and ancillary facilities Obtain Licence to Construct the Underground Characterization Facility

YEAR 18

↓

Construction and Commissioning of the Underground Characterization Facility

↓

Begin site-specific Research & Development to confirm suitability of site.

↓

Collect data from Underground Characterization Facility, conduct research to support design and operating licence for deep geologic repository

↓

YEAR 30

Construct and Commission deep geologic repository and ancillary facilities and obtain **Operating Licence** for deep geologic repository and ancillary facilities

↓

Obtain **licence** to transport used fuel

↓

Transport used fuel to site, **repackage** and **place** used fuel in deep geologic repository

YEAR 60

↓

Extended in-situ monitoring from access tunnels

↓

YEAR 130

Obtain **Licence to Decommission** - and **close and decommission** deep geologic repository

YEAR 141

↓

Close access tunnels and shafts, dismantle borehole monitoring.

YEAR 155

During the siting phase, a preliminary conceptual deep geologic repository design would be prepared for each site being evaluated. Design work would be completed for the surface and underground facilities primarily to establish the access, utility and infrastructure requirements. These requirements would be assessed during initial site screening to ensure that they could be met at potentially suitable site locations in the areas selected for detailed evaluation. Details of the environmental and deep geologic repository monitoring program and the plan to incorporate this program into subsequent site evaluation activities would be developed. Following the selection of a preferred site, a preliminary deep geologic repository design specific for the site would be completed prior to entering into the environmental assessment process and the licensing process.

Once an application for site preparation is made or intent to apply is given an environmental assessment will be required. The implementing agency would be required to demonstrate, during the Environmental Assessment process, that there would be no significant adverse impact on the environment resulting from the construction, operation, decommissioning and closure of the deep geologic repository (and during the postclosure period). The Environmental Assessment will require the preparation of Environmental Assessment Guidelines, site evaluations, a comprehensive survey to measure and record the current background conditions at the proposed site, a preliminary safety assessment, and Environmental Assessment technical studies and report. All of this would be done consistent with a public engagement plan approved by the regulator.

The end point of the siting phase would be the receipt of a siting licence and a construction licence, the latter giving regulatory approval to begin construction of the deep geologic repository facility on the preferred site. It is anticipated that the construction licence would be a staged licence, where the first stage is the construction of the underground characterization facility and further construction activities would depend on acceptable results obtained from the site evaluation provided through operation of the underground characterization facility.

Construction Phase

The construction phase (Years 19 – 29) begins with the receipt of regulatory approval to begin construction and ends when the commissioning of the facilities is completed prior to receiving the first formal shipment of used fuel for emplacement. It involves constructing the infrastructure and surface facilities needed to emplace used fuel, the underground access ways and service areas, and a portion of the underground rooms for used fuel.

It is anticipated that the construction licence may be provided as a staged licence, initially providing approval for the construction of the underground characterization facility, and identifying specific requirements to be met prior to the start of full-scale construction of the facilities. A period of underground data gathering and evaluation in the underground characterization facility would be used to improve the definition of the geotechnical parameters and confirm suitability of the site, provide the basis for the detailed design of the deep geologic repository, and validate licensing assumptions.

When the licence requirements have been met and the approval of the regulator obtained, construction of the full-scale deep geologic repository facility and its ancillary facilities can begin. Provision is made in the design for concurrent excavation during the operations phase to provide further rooms in the repository at the required time.

Operation and Extended Monitoring Phase

The operation and monitoring phase (Years 30 – 129) begins with regulatory approval to receive shipments of used fuel for placement under a licence to operate and ends with approval to begin decommissioning activities. This phase includes a 30-year period (Years 30 – 59) during which used fuel is placed into the deep geologic repository rooms and a 70-year period (Years 60 – 129) of extended monitoring. This phase ends when approval is given to initiate decommissioning of the deep geologic repository facilities.

The application for an operating licence will include a final safety analysis report, consistent with the actual design built and in support of the conclusions of the environmental assessment report submitted. Also, the results of the commissioning program will be required prior to granting approval to operate. The licence will specify requirements, particularly in regard to health and safety and monitoring and the onus will be on the licensee to prove compliance. The licence may need to be renewed periodically as specified by the regulator.

The operation phase would involve receiving used fuel transported to the deep geologic repository facility, sealing it in corrosion resistant used fuel containers, placing and sealing the used fuel containers in repository rooms, and constructing and preparing additional repository rooms. After the last used fuel container has been placed in the deep geologic repository there would be an extended period of monitoring and assessing the conditions in the vicinity of the deep geologic repository. The extended monitoring program makes use of the shafts and underground access tunnels while they are still available prior to deep geologic repository sealing in the decommissioning phase. Extended monitoring activities would include environmental monitoring, monitoring used fuel container performance and monitoring rock mass behaviour. The monitoring data would be used to confirm the long-term safety assessment of the sealed deep geologic repository and provide the basis for decommissioning and closure of the facility.

Decommissioning Phase

The decommissioning phase is the period (Years 130 – 141) in the life cycle of the deep geologic repository during which the surface facilities are decontaminated, dismantled and removed. The beginning of this phase is marked by regulatory approval of a licence to decommission. The underground facilities are decontaminated (if necessary) and dismantled, with tunnels and shafts backfilled and sealed. At the end of the decommissioning stage the site will be in a state suitable to allow public use of the surface. However, public access to certain areas will likely be restricted by maintenance of fencing securing ongoing monitoring activities.

Closure Phase

Closure activities (Years 142 – 154) include dismantling the borehole monitoring instruments and sealing of the characterization and monitoring boreholes that are surface based and which may compromise the integrity of the deep geologic repository system over the long term. The remaining surface facilities serving these ongoing monitoring activities will be removed together with all security measures, thereby fulfilling the objective to return the site to green field conditions. Final removal of all institutional control of the facility will require the issuance of a licence to abandon the facility.

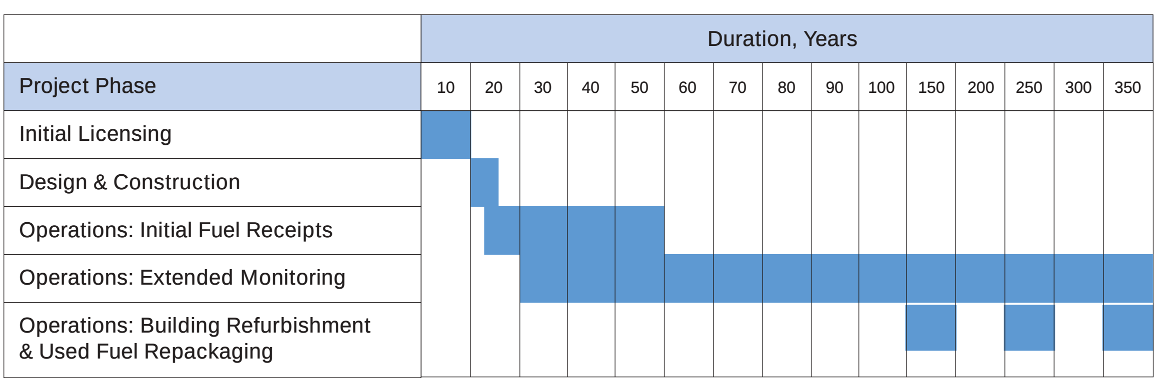
13.2 / Option 2: Storage at Nuclear Reactor Sites

This section presents an estimated timetable and a general description of the implementation activities anticipated for the long-term storage of used fuel at the reactor sites. There are a variety of viable technical alternatives that could be followed at each of the sites requiring different maintenance considerations. Furthermore, different technical methods are currently used at the various sites, which can form the basis for a long-term storage plan. This section does not attempt to provide a comparison of the technical alternatives, but rather identifies the phases of activity that will be required regardless of the method, or methods, selected. Figure 4-16 presents an estimated timetable for the key phases of a management program for reactor-site extended storage. Note that the estimated number of years per phase is not as clear cut as it may be for Deep Geological Disposal on the Canadian Shield or for Centralized Storage because of the variety of sites and the different expected duration of phases for each.

This schedule and the following descriptions are based on information in the conceptual design and cost estimating reports prepared by consultants for the Joint Waste Owners. (See conceptual design reports at www.nwmo.ca/conceptualdesigns).

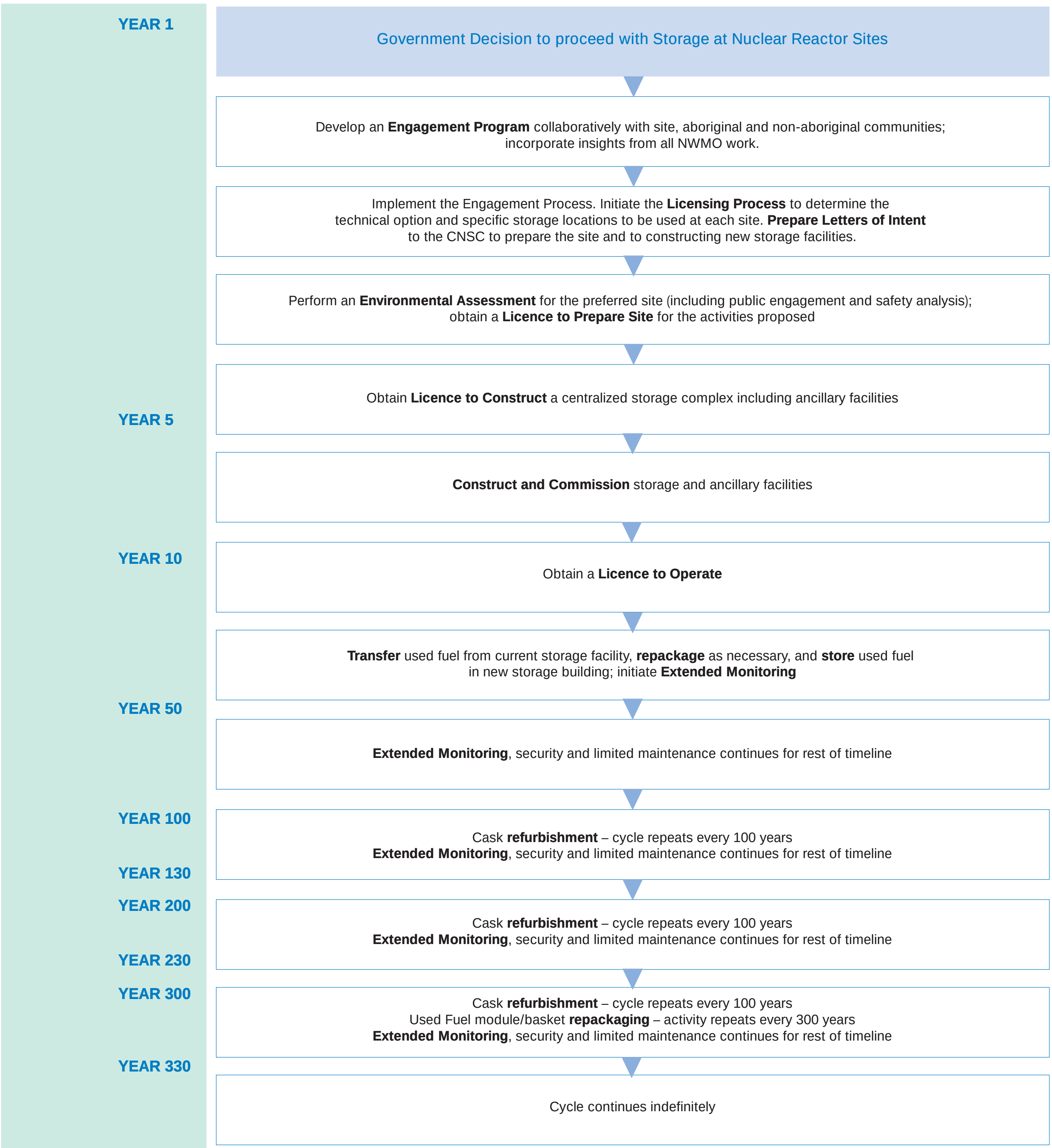
The estimated schedule given here assumes that new storage structures and possibly new dry storage technology are implemented. Due to the varying size of the facilities and the varying fuel inventories at the various sites, initial fuel receipt may be ongoing at some locations while construction is still occurring at others or extended monitoring may have begun at others.

Figure 4-16 Overall Work Schedule for the Storage at Nuclear Reactor Sites



Note: Extended Monitoring and Building Refurbishment/ Used Fuel Repackaging activities continue in perpetuity, based on a 300-year cycle.

Figure 4-17 **Activity Flowchart for Storage at Nuclear Reactor Sites**



Initial Licensing Phase

This initial phase begins after a government decision is made to continue to manage the used fuel at the reactor sites and ends when all approvals have been received to construct the necessary storage structures and implement the selected storage technology.

This phase begins with an extensive review process of the alternatives to determine whether to continue using the existing dry storage facilities for extended storage or to implement new dry storage technologies in some, or all, of the sites. Following this, siting and conceptual design studies will be carried out on each reactor site, taking about one year to complete. When complete, letters of intent would be sent to the regulator to prepare sites and to construct new storage facilities. This would initiate the provincial and federal Environmental Assessment process and the preparation of an application for a licence to prepare the site and construct the facility.

During the environmental assessment process the implementing agency will be required to demonstrate that there would be no significant adverse impact on the environment resulting from the construction, operation and maintenance of the reactor site storage facility. The environmental assessment will require the preparation of Environmental Assessment Guidelines, site evaluations, preliminary safety assessment, preliminary decommissioning plan and environmental assessment technical studies and report. All of this would be done consistent with a public engagement plan approved by the regulator.

Construction Phase

The construction phase is estimated to take about two years, considering it begins with regulatory approval to begin construction and ends when the facilities are commissioned and ready to receive used fuel from existing interim storage. It involves clearing of land, surface and/or underground excavation, construction of processing buildings, ancillary facilities, and construction of at least the first stage of the storage building. Provision is made in the design for construction and expansion during the initial fuel receipt phase to provide further storage capacity as required concurrent with interim storage.

Once commissioned, an application for a new or modified operating licence will be prepared to allow for the new buildings and structures to receive, process and store the used fuel. The application for an operating licence will include a preliminary decommissioning plan and a final safety analysis report, consistent with the actual design built and the anticipated activities. The final safety analysis results must also prove to be consistent with the conclusions of the Environmental Assessment report.

Operations: Initial Fuel Receipt Phase

The initial fuel receipt phase begins with regulatory approval to receive transfers of used fuel for storage under an operating licence and ends with receipt of the last fuel transfer. This phase may begin prior to completed construction of the entire storage complex, and additional storage capacity may be added in a staged manner as required. The length of this phase varies with the size of the used fuel inventory at each site.

There is a significant amount of activity during this phase. Depending on the technical alternative selected, the used fuel will require conversion in a processing building into a format appropriate for the long-term storage approach selected. The licence will specify requirements, particularly in regard to health and safety and monitoring and the onus will be on the licensee to prove compliance. Two particularly important requirements are environmental protection policies and procedures, i.e. an environmental management system, and effluent and environmental monitoring programs. The licence may need to be renewed periodically as specified by the regulator.

Operations: Extended Monitoring Phase

This phase commences at the end of initial fuel receipts and continues indefinitely, continuing throughout the reconstruction, refurbishment and repackaging phases described in the following subsection. This is a time of routine monitoring of the facility and the environment, as well as continued surveillance and security. The operating licence will include this phase, requiring that particular conditions be met to remain in compliance with the licence. The licence is expected to contain a combination of requirements related to monitoring, reporting, security and facility preparedness to respond to unacceptable monitoring results. Two particularly important requirements are environmental protection policies and procedures, i.e., an environmental management system, and effluent and environmental monitoring programs. This phase does not end as long as the facility is in existence.

Operations: Reconstruction, Refurbishment and Repackaging

Given that the storage facilities and principal containment structures have a finite life span, it will be necessary to move the used fuel from an ageing storage complex to new facilities, in addition to refurbishing and repackaging the storage casks and modules. Depending on the technical alternative under consideration, this may be achieved by the staged building of additional storage capacity on the site, permitting the transfer of fuel containers from one storage location to another. Once the fuel has been transferred and the old storage units emptied, redundant storage structures and buildings would be demolished and new ones constructed.

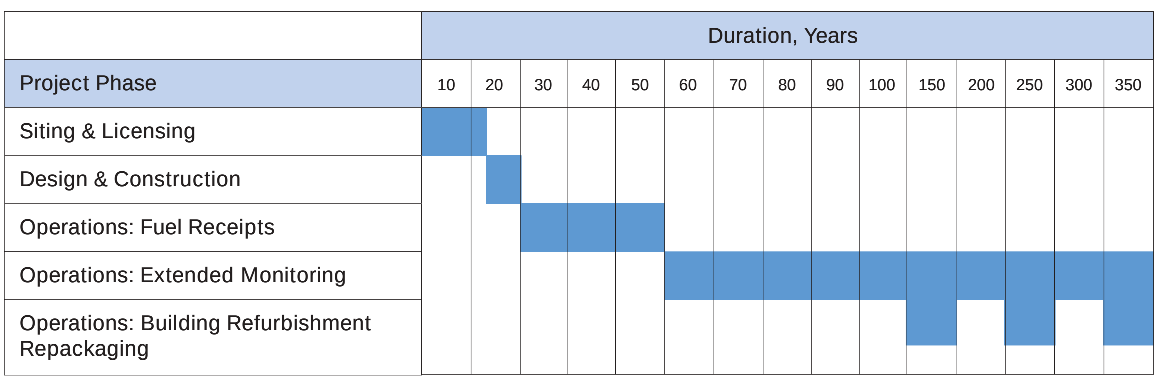
There are two repackaging events that require consideration. One event, based on a 100-year service life of the storage casks, requires the removal of modules or baskets containing fuel from existing storage casks, and repackaging in fresh storage casks. The other repackaging event, occurring every 300 years based on the assumed service life of modules, module canisters and baskets requires the removal and transfer of fuel bundles to fresh modules, module canisters and baskets as required. The used fuel repackaging facility will perform functions relevant to the specific alternative under consideration. It is assumed that the repackaging facility will comprise a shielded cell complex, housed within a large building, configured to perform the activities required for repackaging the used fuel.

The specific refurbishment requirements and the schedule and timing for the different technical alternatives are described in the conceptual design reports, available at www.nwmo.ca/conceptualdesigns.

13.3 / Option 3: Centralized Storage

This section presents an estimated timetable and a general description of the implementation activities anticipated to site, design, construct, operate, monitor and maintain a Centralized Storage facility for the long-term storage of used fuel. There are four technical alternatives that could be followed in implementing the centralized storage concept, including above and below ground options, each with differing maintenance considerations; however the general schedule and phases are consistent for all alternatives. Figure 4-18 presents the phases of the program and the estimated timetable. This is based on the conceptual design and cost estimating reports prepared by consultants for the Joint Waste Owners. (See conceptual design reports at www.nwmo.ca/conceptualdesigns).

Figure 4-18 Overall Work Schedule for Centralized Storage



Note: Extended monitoring and building refurbishment/ repackaging activities continue in perpetuity, based on a 300-year cycle.

Siting Phase

The siting phase covers the time period in which a suitable location for a centralized storage facility is being sought. It begins after a formal decision is made to start the process of finding a suitable site and would end when regulatory approval is received to site and construct the facility at the preferred site (assumed to be Years 1 – 13).

The siting phase would involve developing a siting process that would include both thorough stakeholder consultations and technical assessments on the basis of site characteristics. The acceptability of a site will be determined on the outcome of this siting process. Key components of the siting process include initial public consultations and hearings, development and application of site screening criteria, an Environmental Assessment and the preparation of licence applications. Each of these major components necessarily includes both public involvement/participation and technical assessment and analysis.

The outcome of these public engagement activities would be coupled with the initial site characterization and screening to gain consensus toward selecting a preferred site. The approach would involve initial "desk-top" technical feasibility studies, followed by surface based characterization work, including subsurface exploration by borehole drilling carried out at perhaps two candidate sites in volunteer host communities prior to selecting a preferred site.

During the siting phase, a preliminary conceptual design for centralized storage would be prepared for each site being evaluated. Following the selection of a preferred site, a comprehensive survey to measure and record the current background conditions at the proposed site would be conducted and a preliminary centralized storage design specific for the site would be completed prior to conducting the Environmental Assessment and preparing the application for a licence to prepare the site and construct the facility.

Once application for site preparation is made or intent to apply is given and Environmental Assessment will be required. The implementing agency would be required to demonstrate, during the Environmental Assessment process, that there would be no significant adverse impact on the environment resulting from the construction, operation and maintenance of the centralized storage facility. The Environmental Assessment will require the preparation of Environmental Assessment Guidelines, site evaluations, preliminary safety assessment, preliminary decommissioning plan and environmental assessment technical studies and report. All of this would be done consistent with a public engagement plan approved by the regulator.

Construction Phase

The construction phase (Years 14 – 19) begins with the receipt of a licence approval to begin construction and ends when the commissioning of the facilities is completed, prior to receiving the first formal shipment of used fuel for storage. It involves clearing of land, surface and/or underground excavation, construction of Processing Building and ancillary facilities, and construction of at least the first stage of the storage complex. Provision is made in the design for concurrent construction and expansion during the fuel receipt phase to construct further storage capacity at the required time.

The application for a licence to operate is prepared during this phase. It will include a preliminary decommissioning plan and a final safety analysis report consistent with the actual design built and in support of the conclusions of the Environmental Assessment report submitted. As well, the results of the commissioning program will be required prior to granting approval to operate.

Operations: Fuel Receipt Phase

The fuel receipt phase (Years 20 – 59) begins with regulatory approval to receive shipments of used fuel for storage under a licence to operate and ends with receipt of the last shipment. Following this would be an indefinite period of monitoring.

This phase of operations would involve receiving used fuel transported to the central site and sent to the storage complex. Fuel will arrive in existing storage casks, or be conveyed in transportation casks containing modules or baskets. Depending on the technical alternative selected, some fuel will require conversion in a processing building into a format appropriate for long term storage. During this phase, additional storage capacity will be constructed, expanding the storage complex in a staged manner.

Fuel receipt will be carried out entirely under an operating licence with specific requirements, particularly in regard to health and safety and monitoring. The onus will be on the licensee to prove compliance to these requirements. The licence may need to be renewed periodically as specified by the regulator.

Operations: Extended Monitoring Phase

This phase commences at the end of initial fuel receipts and continues indefinitely, continuing throughout the reconstruction, refurbishment and repackaging phases described in the following subsection. This is a time of routine monitoring of the facility and the environment, as well as continued surveillance and security. The operating licence will include this phase, requiring that particular conditions be met to remain in compliance with the licence. The licence is expected to contain a combination of requirements related to monitoring, reporting, security and facility preparedness to respond to unacceptable monitoring results. This phase does not end as long as the facility is in existence.

Operations: Reconstruction, Refurbishment and Repackaging

Given that the storage facilities and principal containment structures have a finite life span, it will be necessary to move the used fuel from an ageing storage complex to new facilities in addition to refurbishing and repackaging the storage casks and modules. Depending on the technical alternative under consideration, this may be achieved by the staged building of additional storage capacity on the site, permitting the transfer of fuel containers from one storage location to another. Once the fuel has been transferred and the old storage unit emptied, the redundant building would be demolished and a new one constructed. This process is estimated to require 30 years.

There are two repackaging events that require consideration. One event, based on a 100 year service life of the storage casks (applicable to the alternatives Casks and Vaults in Storage Buildings, Casks and Vaults in Shallow Trenches, and Casks in Rock Caverns), requires the removal of modules (or in the case of Casks in Rock Caverns) removal of baskets containing fuel from existing storage casks, and repackaging in fresh storage casks. The other repackaging event, occurring every 300 years based on the assumed service life of modules, module canisters and baskets requires the removal and transfer of fuel bundles to fresh modules, module canisters and baskets as required. The used fuel repackaging facility will perform functions relevant to the specific alternative under consideration. It is assumed that the repackaging facility will comprise a shielded cell complex, housed within a large building, configured to perform the activities required for repackaging the used fuel.

The shielded cell complex is capable of allowing the opening of the storage casks, withdrawal of the modules and withdrawal of fuel bundles from the modules. The fuel bundles are transferred to 'fresh' modules, which would then be loaded into a new storage cask or a new welded canister. Alternatively, the shielded cell complex permits the opening of seal welded baskets and the withdrawal of the fuel bundles within. The fuel bundles are inserted into 'fresh baskets', and the basket assembly seal welded. The repackaging event for each alternative is assumed to require about 30 years. The specific refurbishment requirements and the schedule and timing for the different technical alternatives are described in the conceptual design reports at www.nwmo.ca/conceptualdesigns.

Figure 4-19 **Activity Flowchart for Centralized Storage**

YEAR 1

Government Decision to proceed with Centralized Storage.

↓

Develop an **Engagement Program** collaboratively with potential site, transportation route, aboriginal and non-aboriginal communities; incorporate insights from all NWMO work.

↓

Implement the **Engagement Program**, initiating the **Siting Process** to select preferred site (stakeholder consultations, feasibility studies, site characterization); **Design and Safety Assessment** activities in parallel

YEAR 10

↓

Perform an **Environmental Assessment** for the preferred site (including public engagement and safety analysis); obtain a **Licence to Prepare Site** for the activities proposed

↓

YEAR 13

Obtain **Licence to Construct** centralized storage complex including ancillary facilities

↓

Construct and Commission central storage complex and ancillary facilities and obtain a **Licence to Operate** and **regulatory approval** to receive used fuel shipments

↓

YEAR 18

Obtain **regulatory approval** to transport used fuel

↓

Transport used fuel to site, **repackage** as necessary, and **store** used fuel in storage complex
Initiate **extended monitoring**

YEAR 48

↓

Extended monitoring, security and limited maintenance continues for rest of timeline

↓

YEAR 117

Cask **refurbishment** – repeat every 100 years
Extended monitoring, security and limited maintenance continues for rest of timeline

YEAR 147

↓

YEAR 217

Cask **refurbishment** – repeat every 100 years
Extended monitoring, security and limited maintenance continues for rest of timeline

YEAR 247

↓

YEAR 317

Cask **refurbishment** – repeat every 100 years
Used Fuel module/basket **repackaging** – repeat every 300 years
Extended monitoring, security and limited maintenance continues for rest of timeline

YEAR 347

↓

Cycle continues indefinitely

13.4 / Option 4: Adaptive Phased Management

The Adaptive Phased Management approach is implemented in three phases. In Phase 1, the used fuel continues to be stored at the reactor sites until the necessary siting, approvals, and construction of a central storage facility have taken place, as required. An engagement program is developed as a vehicle for the various public inputs to be made during the implementation, and an oversight and reporting program is instituted.

Phase 1 includes the option to construct shallow underground caverns for centralized storage of used fuel. Also during the first phase, an underground research laboratory (URL) is constructed and site-specific research and development is performed. Phase 2 includes the option to transport used fuel from the reactor sites to a central location for shallow underground storage, and the design and construction of a deep repository supported by the underground research laboratory. In Phase 3, the used fuel is emplaced in the deep repository and extended monitoring is performed until a decision is made to close and decommission the facility. This is followed by postclosure monitoring for as long as necessary.

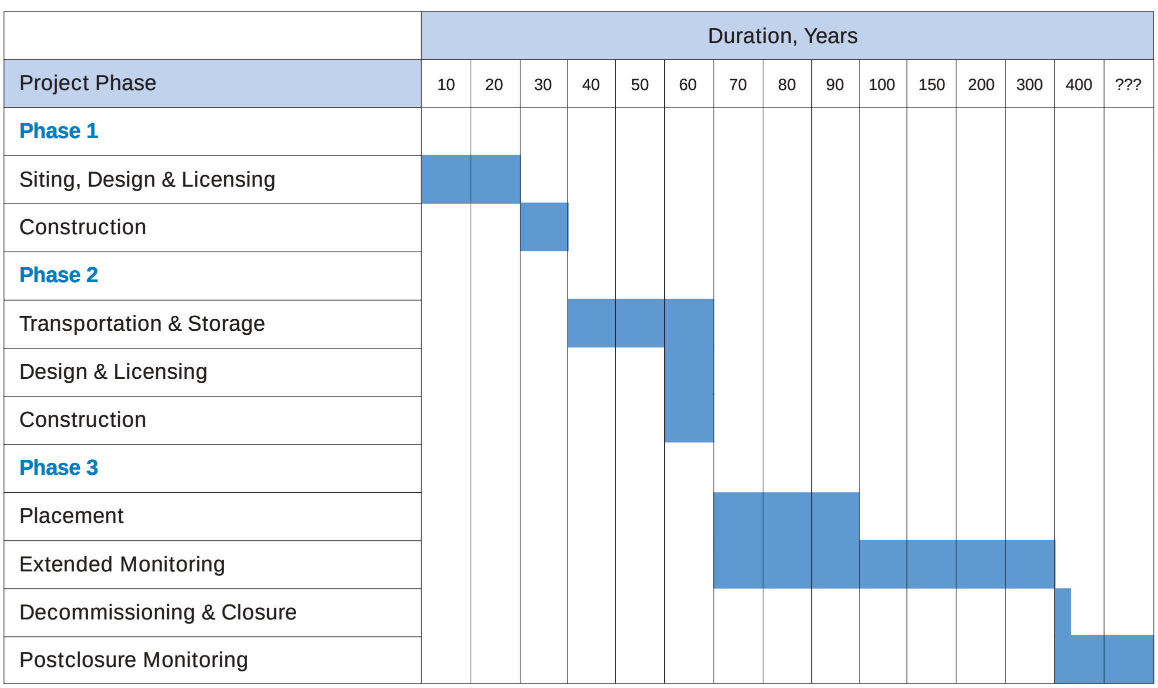
Figure 4-20 presents the phases of the program and the estimated timetable where we have conservatively assumed for planning purposes that a decision has been made in Phase 1 to build the shallow underground caverns for centralized storage and that used fuel is transported from the reactor sites to the central facility in Phase 2.

Phase 1: Preparing for Central Used Fuel Management

Siting, Design and Licensing

In Phase 1, a suitable location for a shallow underground storage facility, an underground research laboratory and a deep geologic repository is sought, and licenses are obtained. The siting portion of Phase 1 begins immediately after a formal decision is made to follow an Adaptive Phased Management approach, and it ends when a licence is received to construct a shallow underground storage facility, an underground research laboratory, and a deep geologic repository (estimated to be Years 1 – 19). It is likely that the construction licence for the deep geologic repository will be granted provisionally requiring that specific conditions be met (such as acceptable data from the underground research laboratory, and the safety analysis based on the

Figure 4-20 Overall Implementation Schedule for Adaptive Phased Management



final design) prior to initiating construction of the deep repository later in Phase 2.

The first activities will be developing an engagement program and instituting an oversight and reporting program. The engagement program and siting process will be developed in collaboration with people and communities from areas potentially affected including Aboriginal Peoples. Based on input from this engagement program, a process will be developed and immediately implemented to determine site acceptability. The major components of the siting process will include stakeholder consultations and technical assessments. Other key activities in this phase include initial public consultations and hearings, development and application of site screening criteria, an Environmental Assessment, and the preparation of licence applications. Each of these components necessarily includes both public involvement/participation and technical assessment and analysis.

A preliminary conceptual shallow storage facility, an underground research laboratory, and a deep repository design would be prepared for the sites being considered. Design work would be completed sufficiently to establish access, utility, and infrastructure requirements as part of initial site screening of areas selected for detailed evaluation. Following the selection of a preferred site, a shallow underground storage design specific for the site and a preliminary design for the underground research laboratory and deep geologic repository would be completed prior to conducting the Environmental Assessment and licensing processes.

The environmental assessment and application for a site preparation licence will need to take into consideration the impacts from all facilities intended for the site, even if they will not be built for decades to come. The implementing agency will be required to demonstrate, during the environmental assessment process, that there would be no significant adverse impact on the environment resulting from the construction, operation, decommissioning and closure of all the facilities intended for the site. The environmental assessment will require the preparation of Environmental Assessment Guidelines, site evaluations, a comprehensive survey to measure and record the current background conditions at the proposed site, a preliminary safety assessment, and environmental assessment technical studies and reports. All of this would be done in concert with a public engagement plan approved by the Regulator. Although there may be Environmental Assessments required in subsequent phases, we expect that they would be based on this major Environmental Assessment completed in Phase 1.

Construction

The shallow underground storage areas, the infrastructure and surface facilities, and the underground research laboratory will be built during Phase 1 construction (estimated to be Years 20 – 29). This period begins with regulatory approval to begin construction and ends when the commissioning of the facilities is completed such that the shallow storage may receive used fuel and site-specific research and development may be performed at the underground research laboratory.

The storage areas of the central facility will be built as a series of shallow rock caverns excavated at a nominal depth of 50 metres below surface and accessible by ramp. As for the underground research laboratory, the underground access ways and service areas, and a portion of the underground rooms for used fuel will be constructed at a nominal depth of between 500 and 1,000 metres below surface and accessible by shaft. It is anticipated that the underground research laboratory may require modification or expansion during the operation phase depending on research findings.

Phase 2: Central Storage and Technology Demonstration

Transportation and Storage

This is when the used fuel is transported from the reactor sites to the central site and placed in shallow underground storage. This period begins when a decision has been made to transport the used fuel to the central location, and the decision has been developed based on input from the engagement program. Transportation can only begin when the central facility has been granted an operating licence to receive, handle, and store used fuel shipments. As well, regulatory approval will be required for the transportation routes and method, including the packages and transport containers that have been designed and licensed for this purpose. It is estimated that transportation will continue for approximately 30 years (Years 30 – 59).

The mode of transportation (road, rail or water) and the routes that will be utilized will depend on the location of the central facility, technical requirements and the recommendations of the engagement process developed in Phase 1.

Design and Licensing

It is estimated that a decision could be made to place fuel in a deep repository on or about Year 50. As with the decisions on siting and transportation, this decision is subject to the engagement and oversight programs developed in Phase 1. A decision to place fuel in a deep repository would mark the beginning of another phase in which the design would be finalized and regulatory approvals would be sought for an operating licence for the deep repository and ancillary facilities. This period is expected to last about 10 years.

During this time, the final deep repository design will be based on underground data gathering and evaluation in the underground research laboratory which will be used to confirm the suitability of the site, provide the basis for the detailed design of the deep repository, and provide validation of assumptions made in the final safety analysis report. At this time, the repository design, which was initially prepared in Phase 1, may be updated depending on technical conditions and regulatory expectations at that time. With the licence requirements met and approval of the Regulator obtained, this phase will end and construction of the deep repository and its ancillary facilities will begin.

Construction

The deep repository placement rooms will be constructed for the purpose of receiving used fuel. This period formally begins with the decision to construct and ends when the repository rooms and surface facilities have been commissioned to receive, process and store used fuel. The initial construction is expected to last about 10 years, although provisions are expected for concurrent excavation during Phase 3, thereby providing further rooms for used fuel at the required time.

An application for an operating licence will be made in parallel with construction activities, including a final safety analysis report. Also, the results of the commissioning program will be required prior to granting approval to operate.

Phase 3: Long-term Containment, Isolation and Monitoring

Placement

Placement (estimated Years 60 – 89) begins with regulatory approval under an operating licence for the deep repository and ends when the last fuel bundle has been placed and an extended monitoring program is initiated. The central facility will place used fuel in a network of horizontal tunnels and rooms excavated in stable rock at a nominal depth of 500 to 1,000 metres below surface. Durable used fuel containers made of corrosion-resistant material will be placed within the rooms or in boreholes drilled into the floor of the rooms. Used fuel containers are assumed to be placed in the deep repository over a 30-year operating period.

The operating licence will specify requirements, particularly in regard to health and safety and monitoring and the onus will be on the licensee to prove compliance. Finally, the licensee may be required to report on the status of the facility and compliance with the licence and the used fuel management program according to requirements of the engagement and oversight programs. The licence may need to be renewed periodically as required by the regulator.

Extended Monitoring

Extended monitoring begins after the used fuel is placed in the deep repository and ends when a decision is made to backfill and seal the deep repository, and approval is given to close and decommission the facilities. The extended monitoring program will take place in-situ at repository depth, making use of the shafts and underground access tunnels. Extended monitoring activities would include environmental monitoring, monitoring used fuel container performance, and monitoring rock mass behaviour. The monitoring data would be used to confirm the long-term safety of the repository and provide the basis for decommissioning and closure of the facility. After closure around Year 300, postclosure monitoring of the facility would take place from the surface if necessary.

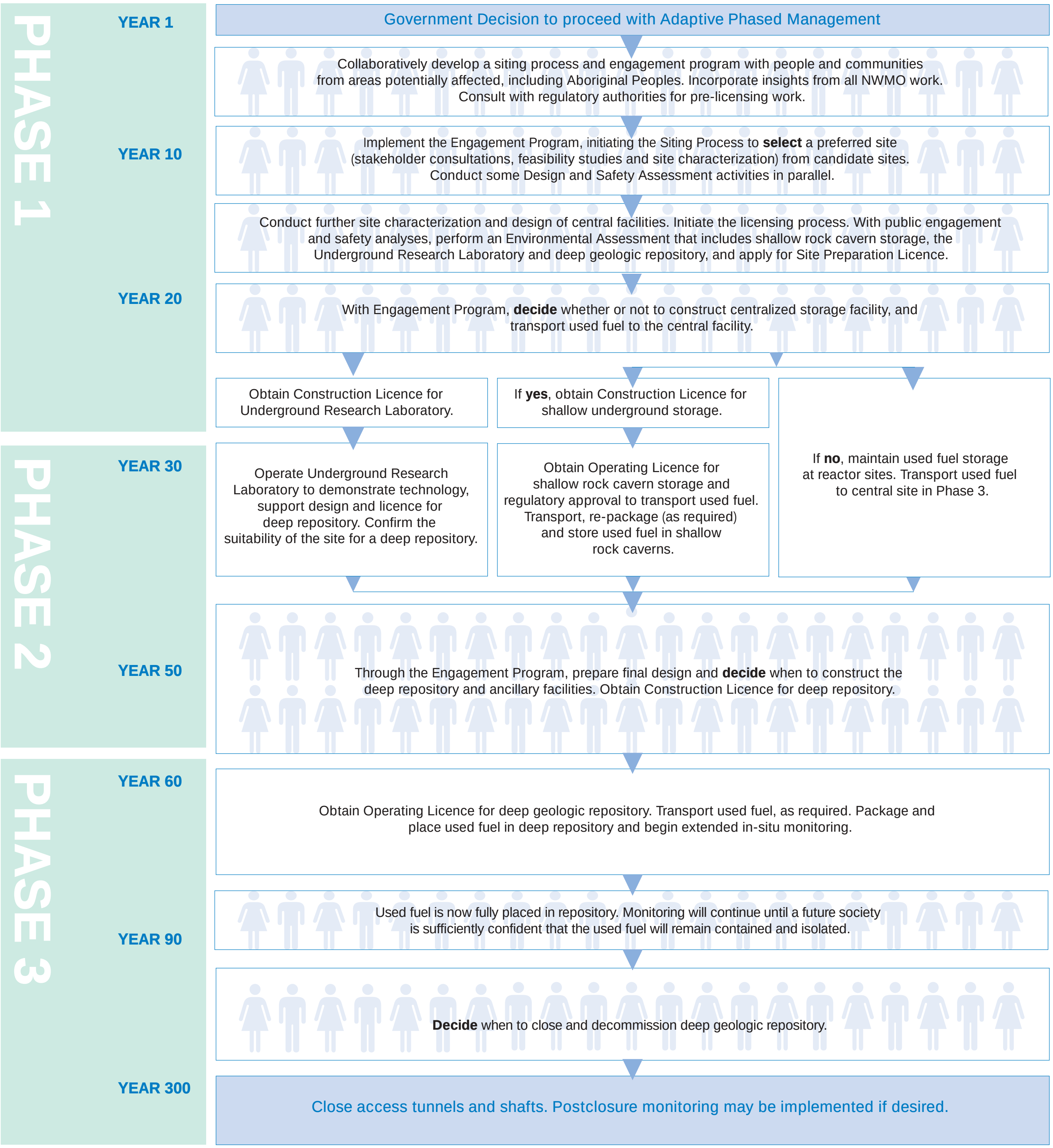
Decommissioning and Closure

Decommissioning begins when a decision is made to backfill and seal the deep repository, and the regulatory approval is granted to do so. This would be one of the last decisions that would need to be supported by the engagement program, and the possible benefits of closing or leaving open would need to be determined at that time. It is estimated that a reasonable time for this decision would be around Year 300, and the activities would require about 25 years. During decommissioning the surface facilities are decontaminated, dismantled and removed. The underground facilities are decontaminated (if necessary) and dismantled, with tunnels and shafts backfilled and sealed. At the end of the decommissioning stage the site will be in a state suitable to allow public use of the surface. However, access may still be denied by maintenance of fencing and secure ongoing monitoring activities.

Postclosure Monitoring

After the closure of the deep repository and the decommissioning of all facilities at the central site, postclosure monitoring could take place at the surface. This would continue indefinitely until a decision was made to end all activities associated with the deep repository.

Figure 4-21 **Activity Flow Chart for Adaptive Phased Management**



CHAPTER 14 / ADDRESSING SOCIAL, ECONOMIC AND CULTURAL EFFECTS

Nuclear Fuel Waste Act (*NFWA*) reference:
12. (6) Each proposed approach must include an implementation plan setting out, as a minimum,

(a) a description of activities;

(b) a timetable for carrying out the approach;

(c) the means that the waste management organization plans to use to avoid or minimize significant socio-economic effects on a community's way of life or on its social, cultural or economic aspirations; and

(d) a program for public consultation.

Section 12(6)(c) of the *Nuclear Fuel Waste Act* requires us to specify the means that will be used "to avoid or minimize significant socio-economic effects on a community's way of life or on its social, cultural or economic aspirations." This requirement is addressed below.

The purposes of socio-economic effects management are to: (1) ensure that people affected and their communities have the capacity to cope with change; and (2) ensure that good relationships are fostered between the proponent, a community and others involved in or affected by a project's development. The management of socio-economic effects is necessarily project and community-specific, and essentially a problem solving activity where solutions are 'tailor-made' to fit the affected community(s), either within an economic region or along a transportation route used for construction material and nuclear fuel transport.

Historically, in the field of environmental assessment, measures taken to minimize or avoid adverse effects are generally referred to as "mitigation." Under the *Canadian Environmental Assessment Act*, "mitigation" refers to measures that serve to prevent, eliminate, reduce or control adverse environmental effects of a project, including restitution for any damage to the environment caused by such effects through replacement, restoration, compensation or any other means. In the field of socio-economic impact assessment, the concept of "mitigation" is broadened somewhat and is referred to as "socio-economic effects management," as it includes not only measures to prevent, eliminate, reduce or control adverse environmental effects; and replace, restore or compensate for damages; but also measures to enhance positive effects and the implementation of practices and procedures for developing and maintaining trust or positive relationships with those affected. More specifically, "socio-economic effects management: involves the coordinated application of mitigation, enhancement, compensation, monitoring and contingency measures, and community liaison measures."

Mitigation refers to actions or measures undertaken with the objective to avoid, or reduce the severity of adverse impacts.

Enhancement refers to actions or measures undertaken with the objective to maximize the potential impacts deemed to be beneficial.

Compensation refers to actions or measures undertaken with the objective to redress or offset the unavoidable or residual adverse impacts of the management approaches. These measures can be impact-related, aiming to offset impacts to a level equivalent to pre-project conditions. Compensation measures may also be equity-related, intended to improve the community's share of benefits over costs. Equity-related compensation is often referred to as an incentive.

Monitoring and Contingency Measures can take the form of policies or programs designed to ensure a timely and appropriate response to potential problems and unanticipated adverse impacts. These contingency measures may involve the application of mitigation, enhancement or compensatory measures.

Community Liaison Measures are policies, programs or administrative procedures aimed at establishing and maintaining cooperative, non-adversarial relationships between the project proponent, project workers, the local community, and various levels of government in order to build commitment to the project and the effects management process and to address some of the more intangible social impacts related to public risk perception.
Source: www.nwmo.ca/assessments

Through our discussions with Canadians and drawing from recent developments both here in Canada and abroad, we have found that a significant evolution in understanding continues to take place regarding how to best address social, economic and cultural implications of development. These insights are particularly important to apply to the development and operation of a facility to manage used nuclear fuel, given its unprecedented nature and time horizon.

At the very heart of this evolution is the recognition that short-term solutions are rarely effective, and that mitigation of adverse effects, on its own, is also not adequate. Initiatives must be designed to seek positive contributions to the community that will continue over the long term. Further, the issue is not simply one of jobs, income, or tax revenues. More fundamentally, it is an issue of peoples' future and the degree of confidence that is held that this future will unfold in a manner that is consistent with closely held values and priorities. This touches the heart of a community's culture. If synchronicity between a proposed project and people's values is not evident, the project may be seen as a threat to the fabric of community life, and be vehemently opposed.

We believe that such an alignment is possible. Its achievement represents a special opportunity for both the NWMO and any eventual host community and surrounding region. The key to success lies in how the citizenry are directly involved in the decisions that affect their current and future way of life. With involvement, trust can emerge; without it, trust is unlikely.

Thus, we opt for involving people starting with the collaborative design and implementation of the process of engagement itself and extending through to collaborative design and implementation of measures to address socio-economic and cultural effects of NWMO activities. Implemented gently, over time, collaboratively and with integrity, the long process of designing, building, and operating a used nuclear fuel management facility can serve as a bridge to a community's sought future.

14.1 / What are Potential Socio-Economic Effects?

Socio-economic effects (or changes to the socio-economic conditions) are determined by many factors including:

- Existing or baseline conditions in an area such as the stability of the size of the local population;
- Key project or program factors that may create effects including estimated workforce requirements, infrastructure needs, and approach to decision-making;
- Changes to traffic patterns and economic flows within a region;
- The nature of the changes, including whether they are direct or indirect, of great or small magnitude, short or long duration, their significance and reversibility; and
- The community's own goals and aspirations and the degree that those affected have the opportunity and ability to participate in, and have some measure of control over, the outcome of decisions that will affect their lives and livelihood.

The socio-economic effects may vary according to the stage or phase of a project. Those produced during a site selection process may be completely different from those occurring during the operation of a specific facility. Identification and determination of socio-economic effects require dialogue with the people in the communities that may be affected.

Socio-economic effects ripple out across a community and region. There are direct effects from a project, such as the employment and wages earned. This in turn, creates indirect effects, such as the impact on goods and services purchased by that worker. In addition, there are tertiary effects. For example, if the work environment leads to the acceptance of a safety culture or an attitude towards co-workers that extend to the community, these are called tertiary effects. In this case, they would be educational in nature, and might lead to fundamental cultural changes. Tertiary effects are often much longer term in nature than direct and indirect effects, and for a project such as the long-term management of used nuclear fuel, they can be very significant indeed.

It is also important to think about socio-economic effects beyond the marketplace. These include effects on faith and cultural oriented activities, the wide range of volunteer activities, recreational activities, housework, and subsistence activities. These are activities that are essential to the fabric of community life. Yet, they often play little or no role in standard market-oriented economic analyses. However, in small communities, particularly Aboriginal communities, these aspects of traditional life carry great importance. The internal cultural and social structure of Aboriginal communities is vulnerable to pressures that arise from development activities.

The linked issues of fairness and justice lie at the centre of many socio-economic concerns. If the distribution of costs, benefits, risks and responsibilities is perceived as fair and just, a sense of integrity emerges. Individuals, organizations and communities can open to many possibilities in the belief that their place will be respected. However, if a sense of unfairness arises, rather than a sense of integrity, it is bitterness, contempt, and even helplessness that come to dominate. Under these conditions, people lose any confidence that they can control their own future. It is for this reason that fairness and justice figure prominently in both the assessment process and the ongoing implementation strategy.

Following is a listing of some common socio-economic effects that may be associated with the long-term management of used nuclear fuel. They are offered as examples of changes that may occur, not predictions of what is likely to occur.

Table 4-10 Potential Socio-Economic Effects and Mitigation Measures by Project Activity

Project Activity with order-of-magnitude estimates of time duration and employees on site	Potential Socio-Economic Effects and Mitigation Measures
Transition to Decision	This period exists between the filing of the NWMO Study Report (November 2005) and the taking of a decision by the government. • Community debate about the implications of the chosen management strategy and/or the acceptability of hosting a facility over the long term. This debate can be potentially divisive within a community, or serve to bring a community together in a strengthening way. • Effectively designed processes can lead to enhanced confidence building and capacity to participate through, for example, (1) continued development of community familiarity with issues through ongoing dialogue; (2) continued development of language capacity for Aboriginal Peoples; (3) development of technical knowledge; (4) for the NWMO, a growth in capacity to include others in the dialogue, in particular Aboriginal People and their Traditional Aboriginal Wisdom and Knowledge in deliberations.
Siting Process	In generic terms, this activity will begin in the “Transition to Decision” phase above. However, with the government decision, activity will begin to gather momentum and, over time, will become increasingly specific in terms of geographic location. • Community debate, potential effects about the acceptability of entering into a feasibility study or site selection process; depending on the nature of this discussion, the outcome can range from a strengthening of community cohesiveness to a significant rupture of cohesion. • Effectively designed processes can lead to enhanced confidence building and capacity to participate through (1) continued development of community familiarity with issues through ongoing dialogue; (2) continued development of language capacity for Aboriginal Peoples; (3) development of social, cultural, economic, environmental, and technical knowledge; (4) for the NWMO, a growth in capacity to include others in the dialogue, in particular Aboriginal People and their Traditional Aboriginal Wisdom and Knowledge in deliberations. • Potential change in land values – could be up or down, depending on location and influencing activity.
Site Characterization and Design; Environmental Assessment process Total time approximately 10 to 20 years Estimated workers on site variable, generally about 25 could peak for short durations several times that amount	From this point onwards, a specific site has been chosen while the final transportation corridors may still be under discussion. • Once the site(s) has been chosen, a significant responsibility accrues to the host community in terms of its capacity to engage as a host. • Enhanced confidence building and capacity to participate through (1) continued development of community familiarity with issues through ongoing dialogue; (2) continued development of language capacity for Aboriginal Peoples; (3) development of social, cultural, economic, environmental, and technical knowledge; (4) for the NWMO, a growth in capacity to include others in the dialogue, in particular Aboriginal People and their Traditional Aboriginal Wisdom and Knowledge in deliberations.

Table 4-10 (cont'd) **Potential Socio-Economic Effects and Mitigation Measures by Project Activity**

Project Activity with order-of-magnitude estimates of time duration and employees on site	Potential Socio-Economic Effects and Mitigation Measures
Construction Total time: up to several decades Estimated workers on site will range from about 600 to 800 for Option 1: Deep Geological Disposal and Option 4: Adaptive Phased Management Fewer workers will be required for Option 2: Storage at Nuclear Reactor Sites and Option 3: Centralized Storage. Numbers may peak at higher levels for durations of a few years	The construction phase will be marked by a significant influx of workers and a heightened level of activity. As a result, significant socio-economic effects can occur and their careful management is crucial. For Geological Disposal and Adaptive Phased Management, there will be fluctuations in activity levels above a relatively high base level. Particular attention will have to be paid to these peaks. Each of the following examples can lead to a significant contribution to the evolution of the community or difficulties, depending upon how they are managed. • Influx of non-local workers may disrupt community cultural, social, and health conditions; Aboriginal communities may be particularly at risk. • Influx of higher wage-earning workers into the community may affect local wage profile. • Demand for skilled trades or wage levels may result in movement of local workers from one industry to another. • Flow of dollars into the local economy may cause a rise in the level of economic activity while the construction period is on to be followed by a difficult drop if not carefully planned and orchestrated. • Infrastructure development can lead to improvements of local infrastructure: transportation, communication, education, health, recreation; however, demand for such infrastructure may push local community to build facilities which may be difficult to support in the absence of the construction activity that led to their creation in the first place. • Increase in demand for supplies and services may over-tax community infrastructure if not properly prepared for: water, sewer, waste disposal, utilities, emergency response, community and regional administrative services, recreation facilities, etc. • Vehicular traffic may be problematic for community if not carefully managed: noise, dust, traffic and visual impacts.
Operation: fuel transportation and emplacement, ongoing research and development Total time: about 30 years Estimated workers on site: about a hundred	In theory, during this phase, socio-economic effects should stabilize for approximately 30 years. Operations-related activities can introduce changes to the socio-economic characteristics of an area such as: • Workforce/labour changes, as construction-related workforce and labour are replaced with stable operating workforce for fuel placement activities. • Changes to local/regional spending for payroll, materials, services. • Infrastructure maintenance, including access routes maintenance. • Off-site service requirements, including water, sewer, waste disposal, utilities, emergency response, administrative, etc. • Physical attributes (noise, dust, traffic, visual effects, etc.) With its stability, there is significant opportunity in this phase to contribute to the evolution of community culture in a way that is consistent with community values and priorities.
Operation: post fuel placement Duration of this phase is indefinite Estimated workers on site about 30 for security, monitoring and reporting	The high level of activities has gone to be replaced by low level of continuous monitoring, regardless of the management option chosen. • Socio-economic and cultural effects will be at a consistent, but low, level.
Closure and Postclosure with Monitoring Duration of this phase is indefinite During closure, the number of people on site would rise to about several dozen. Later, a few workers would be required for monitoring as long as it was maintained.	For Centralized Extended Storage and Reactor Site Storage, this phase will never arise. For Deep Geological Disposal and for Adaptive Phased Management, if and when a decision is made to permanently close the facility, a relatively short period of construction would bring workers onto the site, followed by a low level of activity for as long as monitoring is maintained. • Short initial period of decommissioning activity followed by reduced activity levels.

14.2 / Exploring Innovative Ways of Addressing Socio-Economic and Cultural Effects

Over the past several decades, a range of innovative administrative arrangements have emerged to address socio-economic and cultural effects and simultaneously, to create a solid means for ensuring that affected interests are included in key project decision-making processes. Many of these innovations also provide surety to parties that responsibilities will be discharged in a way that is satisfactory to all concerned. Examples of these are described below. An important task for us will be to review the experience of others within Canada and abroad, and to make that information available to interests throughout this process. This then will provide a strong basis for collaboratively designing the kind of administrative arrangements that will work best in the particular circumstances that are faced in this project.

Innovations in Addressing Socio-Economic Effects

Innovative arrangements in Canada's North. Over the past several decades, and perhaps sparked by the innovative mid-1970s work of the Berger Commission on the Mackenzie Valley pipeline, Canada's north has seen a range of innovative instruments struck to address Aboriginal and northern concerns related to a range of resource developments. Co-management agreements, socio-economic agreements, impact and benefit agreements are some of the labels that have emerged. Mining, pipeline development, gas and oil developments, hydro-electric power developments have all played a part. Some of these arrangements have worked well, but some have not. In the Yukon, a new *Yukon Environmental and Socio-Economic Assessment Act* has just come into being that is setting a whole new standard for assessment. This body of knowledge needs to be carefully reviewed by the NWMO and the lessons learned brought to bear in a way that works for effective long-term management of used nuclear fuel.

The Stillwater Good Neighbourhood Agreement. In May 2000, a historic agreement was signed between the Stillwater Mining Company (SMC) of Montana and three not-for-profit organizations – the Northern Plains Resource Council (NPRC), Stillwater Protective Association (SPA), and Cottonwood Resource Council (CRC). All three of these organizations play a role in ensuring that quality of life in the region is maintained and improved. The agreement sets out to: (1) minimize the adverse impacts caused by company operations on the local communities, economies, and environment; (2) establish and maintain a mechanism of open lines of communication between the parties to ensure that concerns held by affected residents are addressed; (3) ensure that the community has the opportunity to participate in company decisions that may affect the local communities, economies, or environment (the nature of that participation varies depending on the issue); (4) bind the company and successors, partners, subsidiaries and affiliates for the life of mining operations; and (5) minimize future litigation by utilizing the processes and mechanisms established by the Agreement to resolve disputes.

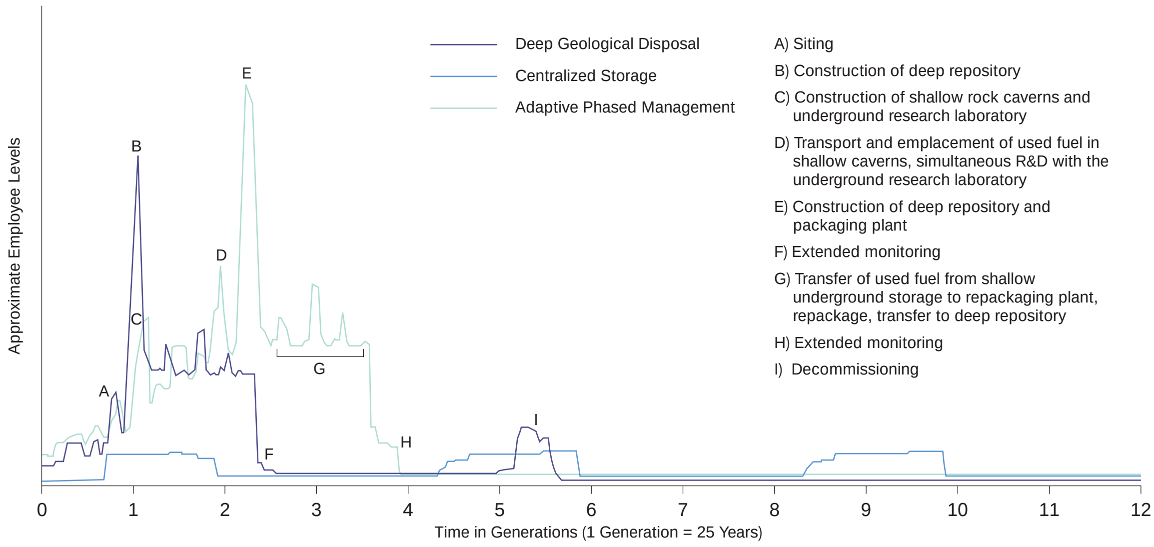
The Antamina Mine's approach to community development and environmental protection. With an initial capital investment of $2.3 billion, Peru's Antamina Mine, which began production in 2001, is the largest "greenfield" mine development in history. Some 10,000 people were employed during the construction phase and 1,400 people are now permanently employed. Components of their innovative approach to community development and environmental protection include: (1) an explicit tripartite perspective involving the company, government, and society; (2) a comprehensive safety program based on building a culture of awareness through standards, training, inspections, audits, and continuous learning; (3) the adoption of internationally accepted principles of social responsibility based on (i) the need to obtain a "social licence" (defined as the consent or acceptance by the principal affected interests) to be able to operate in harmony with the local communities in the project's area of influence; (ii) triple bottom line reporting that includes economic and financial balance, environmental, safety, and health balance, and a social responsibility balance; and (iii) an extensive program of public engagement based on consultation and dialogue; (4) the use of collaborative community-company committees to address a range of environmental concerns and to serve in a monitoring and dispute resolution function; (5) participation by the company in a number or regional environmental working groups involving other companies, non-governmental organizations and local government; and (6) a number of special programs related to agriculture, education, and health.

14.3 / The Particular Issue of Long-Term Community Sustainability

Long-term management of used nuclear fuel is without precedent in terms of the time-horizon over which socio-economic and environmental effects may be felt. As inferred in the above table, the nature of the activity means that there will be rises and falls in the number of workers on sites with a particularly dramatic peak occurring during any construction phase. In addition, the time over which these variations will be experienced on site varies significantly across the four options.

Figure 4-22 provides a conceptual schematic of the relative employment trends (NWMO plus contracted) for three of the four options: Deep Geological Disposal in the Canadian Shield, Centralized Extended Storage, and Option 4: Adaptive Phased Management. Estimates for Option 2: Storage at Nuclear Reactor Sites are not included because many of those involved would be drawn from existing operations of the power producers and just how this would be done is not known. It is not possible to specify exact numbers because of the many factors involved but it is possible to provide order-of-magnitude trends. For example, the highest peak shown (for Option 4)

Figure 4-22 **Conceptual Schematic of the Relative Employment trends for Each Option**



Note: The Reactor-site storage option is complex because it depends on how many workers will be shifted from continuing operations of the power producers.

may reach to about 1,500 and the "average" level for Option 4 from generations one to four would be in the order of 500 people. The portion of these working on site will vary significantly depending on the phase of work.

Figure 4-22 serves to illustrate approximate variations of worker activity over time. Centralized extended storage involves a smaller work force that repeats every several generations in line with requirements for repackaging. Option 1: Deep Geological Disposal involves a single high peak during construction followed by a level of activity several times that of the Option 3: Centralized Storage lasting about a generation. Following closure, this level drops down to a low level.

For its part, Option 4: Adaptive Phased Management climbs to a peak during the time when construction of deep underground facility overlaps with operation of the shallow-underground facility. However, what is most interesting in this case, is that even though there are peaks that must be carefully managed, Option 4 builds gradually and extends over about four generations before dropping down to closure and monitoring conditions. This longer duration activity provides a greater window of opportunity for investment in social, human, physical, financial, and environmental capitals. In turn, with involvement in decision-making, there is heightened opportunity for management of socio-economic and cultural effects to be driven by community values and concerns.

Building a strategy to achieve this result in collaboration with any host community is an important task ahead for the NWMO. Direct, indirect, and tertiary effects will all have to be carefully considered over the full project life cycle.

In particular, mechanisms will have be to considered that deal directly with the transition from high to low levels of activity. One possibility is to create a mechanism to ensure that resources for the use of the community are set aside during the high level of activities for drawing on during the low. This kind of thinking was behind development of such funds as the Alberta Heritage Fund, the Alaska Permanent Fund, and the Norwegian Petroleum Fund, amongst others. These kinds of financial mechanisms need to be reviewed to ascertain strengths and weaknesses and whether or not some form of such an approach might be useful in this case.

In sum, the various elements touched on above need to be brought together in a community-oriented strategy for sustainability that provides a blueprint for addressing socio-economic and cultural effects throughout the project life cycle. In building such a blueprint, suggestions may arise for modification to the level or duration of some of the technical aspects of the project to align the overall result with community priorities.

14.4 / Actions to Address Socio-Economic and Cultural Effects

Following a decision by government on a management approach, we will consider the potential effects of the facility and, working collaboratively with the host community, will identify the most appropriate ways of addressing socio-economic effects.

The initiatives below are presented as illustrative of the types of activities that might be considered as the NWMO and the communities address potential effects.

Local Advisory Capacity

Guidance on identifying and managing potential socio-economic effects could be sought from interests that may potentially be affected as well as from experts in the field. This input is essential in providing socio-economic-related insight to us concerning the area hosting the facility, benefiting from Aboriginal knowledge, and serving as an ongoing focus of socio-economic and cultural-related work as implementation proceeds.

Benefiting from International Experience

Opportunities might be sought to ensure an ongoing flow of information, research, insights and experiences from other countries that are studying and implementing long-term management approaches for used nuclear fuel. The insights available from other jurisdictions will be of interest not only to us, but also to the local area identified to host the Canadian facility.

Generic Socio-economic Research

A comprehensive review of potential socio-economic effects and concrete experiences elsewhere, including successful implementation, might be conducted. This type of review might consider mechanisms that have been developed to address long-term community sustainability such as those mentioned in the previous section, as well as those mechanisms intended to ensure effective communication with communities of interest as the project proceeds. A review of the particular socio-economic needs, concerns, and issues (and ways of addressing them) of various special community groups including reactor-site communities and transportation route communities might be undertaken. In addition, consideration of approaches to dispute management might be useful, in light of the overarching importance of seeking fairness and justice in the implementation strategy.

Aboriginal-Specific Research, Development, and Training

The development of Aboriginal language capacity for addressing nuclear and used nuclear fuel-related issues might be continued. Implementation might explore the nature of Traditional Wisdom and Knowledge and its applications for both process- and substantive-related issues of concern related to long-term management of used nuclear fuel. Consideration could be given as to how best to build innovative approaches for effective dialogue within the Aboriginal community and between the Aboriginal and Non-Aboriginal elements of Canadian society using the long-term management of used nuclear fuel as a focus. There may be interest in reviewing ways of maintaining desirable aspects of a traditional life style and traditional economy while also participating in a wage economy.

The socio-economic dimension is key to the success of our strategy for managing used nuclear fuel. There are a growing number of experiences that offer innovative ways of bringing affected individuals, organizations, and communities into decision-making processes and addressing socio-economic and cultural effects in a way that ensures communities themselves remain in control of their own future. The result is an alignment between a given project and citizen values and priorities.

For communities and the NWMO, the way ahead can be marked by trust and integrity, not acrimony. Seen in this light, the effective management of socio-economic effects paves the way for this project to provide real opportunity – an opportunity that brings an overall positive contribution – to people, their communities, and the environment.

CHAPTER 15 / BUILDING AN NWMO ENGAGEMENT STRATEGY

Nuclear Fuel Waste Act (*NFWA*) reference:
12. (6) Each proposed approach must include an implementation plan setting out, as a minimum,

(a) a description of activities;

(b) a timetable for carrying out the approach;

(c) the means that the waste management organization plans to use to avoid or minimize significant socio-economic effects on a community's way of life or on its social, cultural or economic aspirations; and

(d) a program for public consultation.

Section 12(6)(d) of the *Nuclear Fuel Waste Act* specifies that a "program for public consultation" be included as part of our implementation plan.

In addition, section 18 sets out a requirement for triennial reporting after a decision is made by the federal government. Each triennial report must include:

(a) A summary of our activities respecting the management of nuclear fuel waste during the last three fiscal years, including an analysis of any significant socio-economic effects of those activities on a community's way of life or on its social, cultural or economic aspirations;

(b) Our strategic plan for the next five fiscal years;

(c) Our budget forecast for the next five fiscal years; and

(d) Results of our public consultations held during the last three fiscal years with respect to matters (a) and (b).

Legal Requirements for Consultation

There will be a number of regulatory decisions and approvals sought which will involve requirements for public consultation led by the NWMO. For example, in the processes of:

- Approval under the *Canadian Environmental Assessment Act* (*CEAA*) of an Environmental Assessment for a preferred site; and
- Canadian Nuclear Safety Commission (CNSC) approval and issuance of site preparation and construction licenses for a shallow rock storage cavern; an underground research laboratory; and a deep geological repository.

As well, there may be requirements under provincial legislation. There will be regulatory requirements related to public information during all stages of implementation and guidance on these is contained in CNSC Regulatory Guide G-217.

We will ensure that the specific requirements of each of those processes are fully satisfied. These are important and essential consultations. However, we do not consider these sufficient or to be the sole determinants of the NWMO's public consultation and engagement responsibilities.

The NWMO considers sustained engagement with people and communities essential to effective implementation of any management approach.

15.1 / Setting the Context for Effective Engagement

NWMO's Role

The NWMO's role in engagement will evolve. At certain moments, the NWMO will champion its recommendation and in that way, serve as a proponent of a particular way forward. At other times, it may serve as a convener, bringing together particular interests or technical expertise so that insights may be brought to bear on the treatment of an issue. Sometimes the NWMO may empower others and provide resources so that their capacity to participate effectively is heightened.

The NWMO must act with integrity and sensitivity, to make sure what needs getting done does get done under the conditions that have been agreed upon with all the affected interests. We intend to seek a voluntary host community or communities.

From the beginning of its work in November 2002, the NWMO has committed to working collaboratively with communities of interest to design the way forward. So far, we have consulted Canadians who are members of the general public. But we have not explicitly consulted that "community of interest" consisting of the people likely to be affected by the project (apart from communities and individuals located near reactors where the waste is presently stored). This is because there is as yet no proposal, no proponent, and no project. We are engaged in deciding *how* to manage the used nuclear fuel, not *where*. When the government decides on the nature of the management strategy, the process of identifying real site options and transportation routes related to any management facility will begin.

"Consultation" and the Aboriginal Community

On treaty lands, Aboriginal and treaty rights are defined and protected under s.35 of the *Constitution Act, 1982*. In addition, in 1987, the World Commission on Environment and Development (the Brundtland Commission) stated that tribal people must be given a decisive voice in the formulation of resource policy in their areas.

Since then, a series of Supreme Court of Canada decisions has begun the process of formally clarifying the legal duty of consultation owed to Aboriginal People. Most recently in Haida Nation v. B.C. 2004 S.C.C. 73 (handed down on November 18, 2004) the Supreme Court held that the legal duty of the Crown to consult with Aboriginal People is part of a process of fair dealing and reconciliation flowing from the Crown's duty of honourable dealing with Aboriginal People. On the same day, in Taku River Tlingit v. B.C., 2004 SCC 74, the Supreme Court gave some indication of the measures required to comply with the duty of consultation.

These two cases arose in British Columbia, a largely non-treaty area of Canada. Currently, the Supreme Court is dealing with a third case (Mikesew Cree v. Heritage Canada, heard March 14, 2005) that may apply some of the same reasoning to lands covered by treaty.

Throughout our study, we have made best efforts to involve Aboriginal People in the dialogue. This activity is documented in full in Part Two of this report. We have heard that these discussions did not constitute "consultation" as they saw it. The nature of the specific obligation will be clarified as directly affected individuals and communities become more evident.

Drawing from International Experience

Finding ways to achieve effective engagement is an issue that is being dealt with around the world and in many industries. Specifically, the experiences of countries including Sweden, Finland, Japan, the United Kingdom, France, Germany and the United States, amongst others, are all worthy of review to draw lessons and insights from. The work of the OECD's Forum for Stakeholder Confidence, led by the Nuclear Energy Agency, continues to provide an important forum, which brings together international experience in planning and implementing long-term management approaches for radioactive waste.

The evolving lessons will be documented and shared with all of the involved interests in Canada as part of the knowledge base for creating our particular engagement strategy.

15.2 / Defining "Community" and Mapping Interests

We have sought input from the general public, and in particular Aboriginal Peoples. Our reach has been consciously broad. With a decision by government on how to proceed, our engagement will become more focused. Table 4-11 offers a starting point for defining the implicated "community" in the case of the various management options, based on the idea of a geographically defined community of people.

In addition to identifying geographic communities (cities, towns, villages, municipalities, Aboriginal community within a traditional territory), there are important "communities of interest" that will be interested in this project.

These include governments, industries, and civil society in Canada. In addition there are those in the international arena who are contributing to the development of our management approach (for example, by providing scientific or technical advice) or who may be influenced by what we do in Canada.

It will be important to carefully map out the communities of interest, in order to consider their perspectives in the examination of social, economic, and cultural implications. Only then can the NWMO build collaboratively a set of strategies to address those impacts. Responsibilities need to be clearly articulated and confidence developed that the resources required to discharge those responsibilities will be available when needed.

15.3 / NWMO Engagement Strategy

The post-study NWMO engagement strategy will build upon recent engagement activities supported by the NWMO and continue to seek best practices from other domains of public policy and from international experiences

To initiate discussion, the following illustrates possible components of an engagement strategy. Such a strategy should achieve three objectives:

- To continue the exchange of information and enhancement of knowledge between communities of interest and the NWMO;
- To collaboratively build and implement processes that provide opportunities for various interests to participate in the decisions that affect them; and
- To confirm the alignment of our implementation with the needs and concerns of Canadians.

Table 4-11 Describing Implicated Communities for the Four Management Approaches

Management Approach	Communities of Interest
Option 1: Deep Geological Disposal	Cities, towns, villages, municipalities and dispersed population in the vicinity of the site; the Aboriginal community within the affected traditional territory, transportation corridor communities, reactor site communities until all used nuclear fuel is re-located.
Option 2: Storage at Nuclear Reactor Sites	Reactor site cities, towns, villages, municipalities and implicated Aboriginal People.
Option 3: Centralized Extended Storage	Cities, towns, villages, municipalities and dispersed population in the vicinity of the site; the Aboriginal community within the affected traditional territory, transportation corridor communities, reactor site communities until all used nuclear fuel is re-located.
Option 4: Adaptive Phased Management	Cities, towns, villages, municipalities and dispersed population in the vicinity of the site; the Aboriginal community within the affected traditional territory, transportation corridor communities, reactor site communities until all used nuclear fuel is re-located.

Information Exchange and Knowledge Enhancement

Reflection

On completion of our study, we will seek input from participants on their experience with the dialogue to date, and their thoughts on what might be included in our first five-year engagement strategy. An international conference could also be convened to share information and lessons learned.

Generic Socio-economic Research

The generic socio-economic research referred to in a previous chapter would provide important information and additional knowledge during this next transition phase of our work. We envisage undertaking the research in a collaborative manner with both expert researchers and communities of interest.

Aboriginal-Specific Research, Development, and Training

The following tasks might be continued or initiated:

- Development of Aboriginal language capacity for addressing nuclear and used nuclear fuel-related issues;
- Exploration of the nature of Traditional Wisdom and Knowledge, and its applications for issues of concern related to long-term management of used nuclear fuel in terms of both process and substance; and
- Review of innovative ways of maintaining desirable aspects of a traditional life style and traditional economy while also participating in a wage economy.

Collaboratively Building the Engagement Process

Until there is a government decision, a formal implementation plan cannot be developed. However the NWMO will continue to build the foundation for the implementation strategy. At a generic level, consideration must be given to the nature of the dialogue, and approach to site determination. Communities will have to decide if they wish to participate in this process. The dialogue at the local level with Aboriginal communities should continue.

Based on participant input and our experience to date, it would be desirable to develop a multi-year engagement strategy. The strategy would include a full mapping of interests and specific actions to ensure that those interests can contribute to our process.

We will need to continue seeking innovative approaches for effective dialogue among the Aboriginal communities and other Canadian communities using the long-term management of used nuclear fuel as a focus.

Following the government decision and over time, the nature of the dialogue may well go through a progressively more focused evolution. For example, following the broad-based discussions identified above, it may be possible to identify 10 to 15 communities that would be interested in undertaking community-based feasibility studies. This process may take two to three years to complete.

Upon completion of this phase of work, a smaller sub-set of communities may continue to be interested and be prepared to make a decision to undertake community-based site investigations. This work may require three to four years to complete. Following completion of this effort, a very small sub-set, perhaps one or two communities may be prepared to proceed to detailed site investigations that would require four to five years to complete. At the end of such a process, the outcome may be a willing host community.

This progressive evolution will occur over a period of years and the final decision of any community regarding its interest in being a host community will only occur at the end of this process.

The associated engagement process that would go along with this kind of evolution would be tailored to the different interests, their roles, and responsibilities of communities as they become apparent over time. Design of this whole process would begin with the generic review of engagement described above.

A variety of activities will be required to determine if the needs, values and aspirations of Canadians have been incorporated into the multi-year strategy. For example, the three-year reporting period required by our legislation will provide an opportunity to check progress against the values and concerns of those affected by NWMO activities.

CHAPTER 16 / RESEARCH AND INTELLECTUAL CAPACITY

Although the *NFWA* does not require that we address research as part of the implementation plans, we address the issue in light of the significance that research and intellectual capacity will have for the continuous learning and adaptability that we see as integral to implementation plans.

16.1 / The Important Role of Research

Regardless of the approach taken, activities to manage used nuclear reactor fuel will continue for a very long time. Any management program will be expected to apply the best practices available at that time. There is confidence in present best practices for safely handling used nuclear fuel and that such fuel can be properly managed into the future. However, a program that will evolve over a long period of time will have many opportunities for improvements to increase performance, enhance effectiveness, improve understanding, and address arising societal concerns. To realize these benefits, there needs to be a vibrant and robust research and development effort during management program development and execution, a period that will last many generations.

While the role for research and issues of intellectual capacity were not explicitly required as part of our study under the *NFWA*, we believe that there are many important reasons to pursue such a research and development program. Consequently, NWMO is responsible for ensuring that the research program is funded. The program's scope and content will be guided by:

The intrinsic need to embody the principles of continuous learning – The program for the management of used nuclear fuel will evolve over generations. Continuous learning will not just allow, but demand research and development to help assure focus on areas that warrant attention. The result is that best practices will continually improve. Continuous learning also sets a standard for everyone associated with the program that excellence and integrity are the expected hallmarks. Program requirements are set not at minimally acceptable performance and regulatory compliance, but at meeting societal expectations to continually improve upon best practices and adapt to unfolding advances in related fields as the program progresses.

Increased understanding and capabilities that will surely come from research and development can measurably improve performance, reduce uncertainties and address residual concerns. Over time, it is easy to imagine, for example, major advances in geological understanding and predictions, together with improved man-made materials, engineered barrier system designs to isolate the waste, facility and transportation designs, and instrumentation to measure and confirm performance. Similarly, Canadian values and priorities may change, and the ability to adapt to changes will be necessary to maintain citizen confidence.

Preparation for facility siting, design, licensing, development, and operations – The long term management program will evolve through a number of important stages: developing a concept, identifying candidate sites, building relationships with affected communities and organizations, evaluating candidates for adequacy, finalizing designs, obtaining necessary licenses, building the necessary facilities and infrastructure, operating the system, eventually preparing for closure or steady state maintenance, and confirming post operational performance. These stages will occur over at least decades. There will be many opportunities to improve system design, minimize costs, enhance schedules, reduce uncertainties, and assure regulatory and societal requirements.

Assurance of adequate human capacity to manage the program throughout its existence – The extended time-frame of any management program will present the challenge of sustaining an expert workforce to manage and operate the program. A healthy, properly sized, and focused research and development program will help assure the continual refreshment of the qualified, trained staff required for effective program management. Exciting and cutting edge work attracts the best while assuring integration of program operations with advances in scientific and technological capabilities.

Enhanced scientific understanding to improve confidence in predictions, reduce uncertainties, and to evaluate potential program improvements – It is to be expected that research and development conducted over the course of the management program can be applied to markedly improve understanding and narrow the remaining uncertainties about anticipated performance over long time periods. Program managers will be able to use this improved understanding to modify program elements where warranted, to improve expected performance and reduce unnecessary program schedule delays and costs. Of course, it is always possible that improved understanding may open up new questions about system performance, which will call for new avenues of research and development to address the new information.

The ability to confirm performance during and after program operations – Thorough confirmation of performance during development and initial operations and after the operational stage is complete are important steps. These confirmations serve to increase confidence in performance, meet regulatory compliance standards, identify any anomalies, and provide further assurance to the public and stakeholders that the implementers and regulators take their long term stewardship responsibilities seriously. Research and development programs will enhance capabilities to confirm performance through continual improvements, for example, in instrumentation, data acquisition techniques and methods, analytical and modeling capabilities, and computer simulations. Such improvements will be particularly valuable in a staged program.

The obligation to citizens to clearly demonstrate an ongoing capability to manage the enterprise and to respond to their concerns and desires – The management program for spent nuclear fuel is challenging both because of its long duration and because of the intense and widely varying views of the public and affected stakeholders. Citizens and their representatives want to be confident that responsible organizations will maintain the necessary capabilities to oversee and manage program development and implementation. A vibrant and well directed research and development program will help assure the staffing of a cadre of trained and experienced personnel focused on solving anticipated and emerging issues associated with the program throughout its duration.

The ability to enact mid-course corrections in response to new information or societal decisions – Because the management program will last for generations, it is possible, if not probable, that new scientific and technical information and capabilities, and perhaps changes in societal perspectives and desires, will lead to proposals for beneficial changes in program plans and implementation. In this regard, the research and development program will serve two important purposes. It will create the new information and capabilities that can serve as the rationale for subsequent decision making. It will also maintain the expertise and resource base to implement desirable changes.

There are many areas where new information and capabilities may lead to improvements in program implementation or modification of program goals. Some include the continuing development of advanced nuclear power plants, new fuel cycle processes and facilities; potential international or regional institutional changes to allow for multinational ownership or control of sensitive facilities; changes in international policies and treaties; and new developments in partitioning and transmutation of used nuclear fuel and in deep borehole management techniques.

The ability to adapt new capabilities developed external to the program that show the promise of improving program success – Over time, there will be marked changes in many areas of scientific, technical, and social science germane to the management program. One can expect significant advances in geosciences and biosciences and the development of new materials, improvements in computer codes and the modeling of natural and engineered systems, better instrumentation capabilities, new social science insights, and much more. Many of these advances will occur largely outside the program itself, but offer major potential benefits if adapted into the program. The research and development program will allow for identification and adaptation of such advances into the program as warranted.

16.2 / Research Requirements Common to all Management Approaches

Generic Research Requirements

In the sections that follow, we provide examples of some of the areas of research that would be appropriate under any of the four management approaches.

As part of the implementation process, we would identify specific areas requiring study as part of the ongoing engagement program. Beyond the required technical expertise, additional R&D should be conducted on a range of non-technical issues of importance as well, including socio-economics, stakeholder involvement, and public attitudes. It would be important to involve external parties in identifying research of relevance and interest. The research funding should most often be competitively determined and the work carefully peer reviewed.

Some of the topics that may require research effort include:

- Applying traditional wisdom and knowledge – applies to both process issues (starting immediately) and substantive issues (when the site or sites are identified for more detailed assessment);
- Dispute management over the long term;
- Adaptive management as it relates to ongoing social and technical decision-making;
- How to monitor and assess community well-being;
- How to work with a community to ensure that cultural integrity is maintained in a way that works for the community;
- How to smooth out the boom and bust cycle in the adjacent region/community; what mechanisms can be created that can address this in concrete terms; and
- Canada produces its power from the CANDU reactor, which has different fuels than the more predominant light water reactors used elsewhere in the world. Since the wastes residing within the used fuel represent the "source term" of radioactivity, it is important to have an indigenous program that identifies issues of particular importance to Canada and assures that these are carefully addressed.

The scope of our program should be determined in conjunction with early bilateral and international program contacts to build upon the existing data and capabilities in other countries and international organizations. Formal working relations should be established as appropriate with waste management programs in other countries on problems of mutual interest. International collaboration has been a hallmark of radioactive waste management programs. Much of the work can be done collaboratively and information sharing and personnel exchanges can benefit all parties.

International exchanges of research findings make it possible for countries to allocate resources efficiently, sharing information on a wide range of technical considerations.

Human Resource Capacity

To ensure the safe management of used nuclear fuel, we must have access to a sufficient and sustainable number of trained and skilled personnel throughout the development and implementation of a radioactive waste management approach.

It can take a generation to build up appropriate expertise related to used fuel management and disposal, but it can be lost very quickly. It will be important for us to canvass Canadian experience and capabilities and initiate a program to preserve knowledge already gained, and to organize a program with existing talent, focused on issues of particular relevance to the programmatic choice coming out of the November 15, 2005 recommendations and subsequent government decisions. In addition, the program should encourage the broad involvement of the Canadian academic community, with an emphasis on involving the next generation of leaders in research and development, graduate students, post-docs, and young faculty.

We will require expertise and capabilities in a range of fields, including, but not limited to: socio-economics; ethics, finance, public relations, siting and waste management technology. We must ensure that there is an adequate number of qualified personnel with ethical and socio-economic expertise to evaluate and conduct socio-economic impact assessments, manage community agreement negotiations and identify key ethical issues that may impact future generations. There must also be experts qualified to manage the financial aspects associated with such a project. Furthermore, we will require personnel trained in public relations, to develop and implement a comprehensive public engagement plan particularly during the initial siting phase, post government decision on the selected ways forward for Canada. These experts will also be required to ensure that the public's concerns are taken into account throughout the implementation process.

Depending upon the management approach selected, many scientific disciplines will be involved in implementation, possibly spanning earth sciences such as geology, hydrology, geochemistry, seismology, geomechanics and biosciences, as well as climatology, materials development and performance, and corrosion, to name but a few. Implementation may require program capabilities that merge earth sciences with engineering. The combination of experiments, analysis, modeling, simulation and computation are required for system design and even more so for performance assessments that will be the basis of licensing. Careful and sustained programs will have to be nurtured to develop this interdisciplinary need.

Areas of required technical capabilities and expertise include, but are not limited to: project management; risk, cost and benefit analysis; logistical studies; technology evaluations; institutional requirement analysis; code verification and validation; information research; quality assurance; environmental impact assessment; ecological sciences; and transportation equipment design, safety analysis and engineering design.

Expertise unique to used nuclear fuel management include: fuel waste characterization; waste-form behaviour; radiation shielding; radiological safety assessment; occupational radiation exposure management; material sciences and waste package design; and decontamination methods development and management. Many of these disciplines are specialized, therefore these skills may not be transferred over from other industries.

It is anticipated that we will not need to have this range of expertise fully covered with the in-house staff complement. Opportunities exist to contract for external support in many of these areas.

Monitoring of Research Internationally

Chapter 8 addressed the significant expenditures made in Canada on the study of long-term management of used nuclear fuel. In addition to commissioning its own research, Canada will benefit from monitoring the findings from the vast amount of research under way in other countries to further understanding of the long term management of used nuclear fuel.

Over 30 countries have radioactive waste management programs and several (United States, Finland and Sweden) are close to implementing repositories for used nuclear fuel or high level radioactive waste (HLW). The level of funding for research and development activities varies from country to country. The Swedish (SKB) annual used fuel research and development budget is approximately $10 million while the United States (DOE) annual budget at Yucca Mountain is over $500 million ($US). In addition, there are large international research programs such as the European Commission Sixth Framework Programme 2002 – 2006, with a radioactive waste management budget of 90 million Euros over the five-year period.

The research areas under this program cover improvements of fundamental knowledge, development and testing of geologic repository technologies, study of natural analogues and new and improved tools to model the performance and safety of geologic repositories. Also, there is further work addressing partitioning and transmutation technology as well as concepts to produce less waste. France is particularly active in advancing the research and development program for partitioning and transmutation of used nuclear fuel wastes.

The NWMO should keep a "watching brief" on a number of approaches and technical (and non-technical) developments in other countries which, if successful, might lead to eventual improvement or modification of the Canadian program. These may include, but are not limited to:

- Partitioning and transmutation;
- Deep borehole disposal;
- International/regional initiatives regarding the fuel cycle, including spent fuel storage and disposition;
- Reprocessing and associated waste management;
- Engineered materials and barrier development;
- New instrumentation, particularly for performance confirmation; and
- Modeling, simulation, and analytical techniques to evaluate long-term performance

16.3 / Research Specific to Individual Management Approaches

Canadian citizens have told us that regardless of the management approach that is eventually chosen by the federal government, there should be adequate resources dedicated to an ongoing research program associated with the long-term management of Canada's nuclear fuel waste. These resources should be allocated to keep Canadians abreast of new developments in radioactive waste management, both within Canada and internationally, to ensure that new knowledge and new developments can be incorporated into the solution for Canada's used nuclear fuel.

In the sections that follow, we provide examples of some of the areas of research that would be appropriate under different management approaches.

Option 1: Deep Geological Disposal in the Canadian Shield

Deep Geological Disposal involves transportation of the used fuel from each of the nuclear facilities currently in Manitoba, Ontario, Québec and New Brunswick to a central deep geologic repository facility for permanent isolation of used nuclear fuel in Canada. Following a federal government decision to proceed with Deep Geological Disposal, it is expected that it would take about 30 years to site a geologic repository and obtain an operating licence. This initial 30-year period would involve key decisions with respect to selection of used fuel container and sealing system design, selection of host rock formation and selection of the final site for a geologic repository and transportation system to the central facility.

Research and development activities for Option 1 would be required to identify, characterize, engineer, analyze, study, demonstrate and select the appropriate repository technology and final site during the siting and design and construction phase. This research and development would address development of site screening criteria and the site selection process, technical and social site characterization, biosphere and geosphere evaluation, computer model development, repository engineering and safety assessment activities conducted to support the feasibility studies in potential host communities, and the selection of a final engineering design and preferred site to support the safety and environmental impact assessment documents and related licensing activities. It would also include development of used fuel monitoring activities at repository depth, demonstration of used fuel container placement and retrieval technology at underground research laboratories, vault sealing system development, security development work and further development of transportation technology, logistics and implementation schedule.

The research and development program follows the step-wise implementation of the deep repository concept with specific information designed to support the decision-making process. Examples of key decisions during the staged approach to implementation of Option 1 which would be supported by the research and development program include:

- Selection of design alternative (e.g., in-floor, in-room or long horizontal borehole placement of used fuel containers);
- Identification of the site selection process and site screening criteria;
- Selection of candidate sites for the repository from preliminary feasibility studies;
- Selection of the preferred host rock and depth for a repository;
- Selection of the preferred site for the repository;

- Decision to proceed with development of the underground characterization facility at the preferred site;
- Selection of the optimal transportation technology, route and logistics (timing);
- Identification of the repository monitoring system during used fuel container placement operations;
- Identification of the repository monitoring system after used fuel container placement operations;
- Identification of design improvements for the approach during implementation and re-licensing of the facility;
- Review of design from a safeguards perspective;
- Identification of the time period for extended monitoring of the repository (after container placement operations are complete); and
- Decision to decommission and close the facility.

The research and development program during the Siting and Design and Construction phase for Deep Geological Disposal would be between $10 million and $20 million per year. It is expected that the Canadian research and development program would continue its international collaboration and joint research and development program activities with other waste management organizations such as Posiva, SKB, and Nagra and seek opportunities to collaborate with other waste management organizations, as appropriate.

Option 2: Storage at Nuclear Reactor Sites

Storage at Nuclear Reactor Sites involves perpetual storage of used nuclear fuel at each of the nuclear facilities currently in Manitoba, Ontario, Québec and New Brunswick. Following a federal government decision to proceed with Storage at Nuclear Reactor Sites, it is expected that it would take three years to review the storage design alternatives and up to an additional seven years to obtain an operating licence for the facility, depending on the choice of storage technology. This initial 10-year period is crucial for the identification, analysis and selection of the preferred storage alternative at each reactor site in Canada.

During the Siting and Design and Construction phase, research and development would be required to site, characterize, engineer, analyze, study and select the appropriate storage technology for each site. Used fuel storage technology has been developed in several countries and these technologies would be further reviewed to assess their feasibility in Canada. This research and development would support the safety assessment and environmental impact assessment documents and related licensing activities. It would also include development of used fuel monitoring activities, long-term used fuel integrity studies and security development work.

The research and development program follows the step-wise implementation of the Storage at Nuclear Reactor Sites concept with specific information designed to support the decision-making process. Examples of key decisions during the staged approach to implementation of Storage at Nuclear Reactor Sites that would be supported by the research program include:

- Selection of reactor site storage design alternative (e.g., existing or new technology);
- Identification of the optimum monitoring system period for used fuel examinations;
- Identification of design improvements for reactor site storage during implementation and re-licensing of the facilities; and
- Review of design from a safeguards perspective.

The research program during the Siting and Design and Construction phase for Storage at Nuclear Reactor Sites would be several million dollars for each site in Canada.

Option 3: Centralized Extended Storage

Centralized Storage, either above or below ground, involves transportation of the used fuel from each of the nuclear facilities currently in Manitoba, Ontario, Québec and New Brunswick to a central facility for the perpetual storage of used nuclear fuel in Canada. Following a federal government decision to proceed with Centralized Storage, it is expected that it would take about 17 years to site a central facility and obtain an operating licence. This initial 17-year period would involve key decisions with respect to selection of used fuel storage design, location and transportation system to the central facility.

As with the Storage at Nuclear Reactor Sites, research and development would be required to identify, characterize, engineer, analyze, study and select the appropriate storage technology and final site during the Siting and Design and Construction phase. This research would address the engineering and safety assessment activities conducted to support the feasibility studies in potential host communities, development of site screening criteria and the site selection process, technical and social site characterization, selection of a final design and central site to support the safety and environmental impact assessment documents and related licensing activities. It would also include development of used fuel monitoring activities, long-term used fuel integrity studies, security development work and further development of transportation technology, logistics and implementation schedule.

The research program follows the step-wise implementation of the Centralized Storage concept with specific information designed to support the decision-making process. Examples of key decisions during the staged approach for implementation of Centralized Storage which would be supported by the research program include:

- Selection of centralized storage design alternative (e.g., above or below ground);
- Identification of the site selection process and site screening criteria;
- Selection of candidate sites for centralized storage from preliminary feasibility studies;
- Selection of the preferred host rock, depth (if below ground) and site for centralized storage;
- Selection of the optimal transportation technology, route and logistics (timing);
- Identification of the optimum monitoring system period for used fuel examinations;
- Identification of design improvements for centralized storage during implementation and re-licensing of the facility; and
- Review of design from a safeguards perspective.

The research and development program during the Siting and Design and Construction phase for centralized storage would be about $5 million per year.

Option 4: Adaptive Phased Management

Option 4: Adaptive Phased Management involves transportation of the used fuel from each of the nuclear facilities currently in Manitoba, Ontario, Québec and New Brunswick to a central facility for an extended storage period followed by long-term isolation in a deep geologic repository in Canada. Following a federal government decision to proceed with Adaptive Phased Management, it is expected that it would take about 30 years to site a central facility in suitable geomedia such as the Canadian Shield or in the Ordovician sedimentary rock basins and obtain an operating licence. This initial 30-year period would involve key decisions with respect to selection of used fuel container and sealing system design, selection of host rock formation and selection of the final site for a geologic repository and transportation system to the central facility.

The siting period will also continue the necessary research and development of the technology for used fuel storage, transportation and isolation. For example, containers and handling systems for extended storage of used nuclear fuel in shallow underground rock caverns may need a design update. Transportation systems for used fuel will need further development, testing and demonstration. And the mode of transportation: road, mostly rail or mostly water, may need further optimization to meet the needs of potential host communities for the central facility.

Research and development activities for a deep geologic repository will be required to identify, characterize, engineer, analyze, study, demonstrate and select the appropriate isolation technology and final site during the siting phase. This research and development will address development of site screening criteria and the site selection process, technical and social site characterization, biosphere and geosphere evaluation, computer model development, repository engineering and safety assessment activities conducted to support the feasibility studies in potential host communities, and the selection of a final engineering design and preferred site to support the safety and environmental impact assessment documents and related licensing activities. It would also include development of used fuel monitoring activities at repository depth, demonstration of used fuel container placement and retrieval technology at international underground research laboratories, vault sealing system development, security development work and further development of transportation technology, logistics and implementation schedule.

Initially, the research and development would take place at surface laboratories and at international underground research laboratories at generic sites such as the Äspö Hard Rock Laboratory in Sweden. (Canada currently is participating in international research projects at Äspö). Later, the research and development would take place at the underground research laboratory at the preferred site in Canada.

The research and development program follows the step-wise implementation of the Adaptive Phased Management approach with specific information designed to support the decision-making process. Examples of key technical decisions for long-term isolation of used fuel which would be supported by the research and development program include:

- Identification of potentially suitable rock formations at candidate sites for a deep geologic repository (e.g., crystalline rock, sedimentary rock);
- Identification of the site selection process and site screening criteria;
- Selection of candidate sites for a deep geologic repository from preliminary feasibility studies;
- Selection of the preferred host rock and depth for the deep geologic repository;
- Selection of the preferred site for the underground research laboratory and the deep geologic repository;
- Selection of long-term isolation design alternative (e.g., in-floor, in-room or long horizontal borehole placement of used fuel containers);
- Selection of the optimal transportation technology, route and logistics (timing);
- Identification of the repository monitoring system during used fuel container placement operations;
- Identification of the repository monitoring system after used fuel container placement operations;
- Identification of design improvements for a deep geologic repository;
- Review of design from a safeguards perspective;
- Identification of the time period for extended monitoring of the deep geologic repository (after container placement operations are complete) and any impacts on the integrity of the used fuel containers within the placement rooms; and
- Support for a decision to decommission and close the facility.

The research and development program during Phase 1 for Adaptive Phased Management would be between $10 million and $20 million per year. It is expected that the Canadian research and development program would continue its international collaboration and joint research program activities with other waste management organizations such as Posiva, SKB and Nagra and seek opportunities to collaborate with other waste management organizations, as appropriate.

Continuous learning through research and development and monitoring of emerging knowledge will be paramount to informed decision-making in implementing a long-term management approach for used nuclear fuel. Each phase of implementation will require consideration of choices and decisions, with each step informed by our latest understanding of science, engineering, social sciences and the natural sciences. Research will be important in guiding decisions on technology for used fuel management, the detailed site investigations and in monitoring developments internationally in areas that may have relevance in confirming or proposing adjustments to the implementation path.

We believe that ongoing research and development should be a component of our annual business plans. Our research and development program should be reflected in the five-year strategic plans that are submitted to the Minister of Natural Resources Canada in the triennial reports. We should report regularly to the public on its key areas of investigation and how findings have impacted on decisions along the way.

The extent to which the NWMO monitors, considers and reflects emerging knowledge into its plans for managing used nuclear fuel will be essential to building confidence of the public.

We could be assisted by independent third party guidance on matters of such public interest, to confirm the areas of proposed research and our application of key research findings drawn nationally and internationally.

CHAPTER 17 / SERVICES PROVIDED TO OTHER OWNERS OF NUCLEAR FUEL WASTE

Nuclear Fuel Waste Act (*NFWA*) reference:
7. The waste management organization shall offer, without discrimination and at a fee that is reasonable in relation to its costs of managing the nuclear fuel waste of its members or shareholders, to

(a) Atomic Energy of Canada Limited, and

(b) all owners of nuclear fuel waste produced in Canada that are neither members nor shareholders of the waste management organization

its nuclear fuel waste management services that are set out in the approach that the Governor in Council selects under section 15 or approves under subsection 20(5).

12. (5) Each proposed approach must include a description of the nuclear fuel waste management services to be offered by the waste management organization under section 7.

Section 12(5) of the *Nuclear Fuel Waste Act* (*NFWA*) requires us to identify in our study any services to be provided to other waste owners, beyond the nuclear energy corporations. Specifically, those referred to in section 7.

Section 7(a) relates to NWMO's requirement to offer its services to AECL. With respect to implementation in the pre-licensing period, costs to be covered by AECL will be determined and may be set out in an NWMO Membership Agreement which will give effect to the funding formula agreed to by waste owners and presented in section 18(1) of this report. AECL contributes to its own trust fund as required under the *NFWA* to fund implementation following NWMO's receipt of a construction licence. AECL will utilize our services, and pay for them from an allocated proportion of costs as set out in *Financing The Management of Nuclear Fuel Waste in Support of the Nuclear Fuel Waste Act*, available on our website at: www.nwmo.ca/financing.

As such, the services to be offered by us would be in accord with those offered to all other members.

Section 7(b) of the *NFWA* refers to two distinct groups. The first are the existing research reactors at various academic institutions across Canada. The second group would be made up of new market entrants.

The four management approaches under study by us have not identified services to be offered to waste owners other than NWMO Members (Ontario Power Generation Inc., NB Power Nuclear, Hydro-Québec) and AECL. Research reactors within Canada presently disposition spent fissile material in one of two ways. Under existing agreements, waste material is returned to the point of origin. We would not provide services in this instance. In other cases, material would be transferred back to AECL, to be stored at their Chalk River Laboratory, with materials handled and paid for under the NWMO Membership Agreement. In the event that there are new market entrants in the future, the services and fees negotiated by us would be determined, at that time, by the nature of the waste owner's fuel, the volume of material to be managed and an allocation of costs in accord with existing member costs.

CHAPTER 18 / FINANCIAL ASPECTS

18.1 / Funding Formula

The *NFWA* requires us to address the financial aspects of the long-term management of used nuclear fuel.

The annual amount required to finance the management of nuclear fuel waste has two components:

(i) the annual amount required to be contributed to the trust funds set up in accordance with section 9(1) of the *NFWA*, available to the NWMO to implement the management approach following receipt of a construction licence; and

(ii) the annual amount required to be provided to the NWMO to fund their activities prior to receipt of a construction licence.

Nuclear Fuel Waste Act (*NFWA*) reference:
13. (1) The study must set out, with respect to each proposed approach, a formula to calculate the annual amount required to finance the management of nuclear fuel waste.
The report must explain the assumptions behind each term of the formula. The formula must include the following terms:

(a) the estimated total cost of management of nuclear fuel waste, which must take into account natural or other events that have a reasonable probability of occurring;

(b) the estimated rate of return on the trust funds maintained under subsection 9(1);

(c) the life expectancy of the nuclear reactors of each nuclear energy corporation and of Atomic Energy of Canada Limited; and

(d) the estimated amounts to be received from owners of nuclear fuel waste, other than nuclear energy corporations and Atomic Energy of Canada Limited, in return for services of management of nuclear fuel waste.

(2) The study must set out, with respect to each proposed approach, the respective percentage of the estimated total cost of management of nuclear fuel waste that is to be paid by each nuclear energy corporation and Atomic Energy of Canada Limited, and an explanation of how those respective percentages were determined.

(3) The study must set out the form and amount of any financial guarantees for the management of nuclear fuel waste that have been provided by the nuclear energy corporations and Atomic Energy of Canada Limited under the *Nuclear Safety and Control Act*.

Total Cost

The estimated total costs of management of nuclear fuel waste for Options 1, 2 and 3, those defined in the *NFWA*, are set out in the summary cost estimate reports commissioned by the Joint Waste Owners. (www.nwmo.ca/costreview) These reports provide cost estimates for a range of potential fuel bundle quantities derived from a range of potential station lives from 30 to 50 years. The third-party review of the cost estimates commissioned by us concluded that they have been prepared with an appropriate estimating methodology and are suitable for our review and assessment of the magnitude of costs of alternative management options and recommendation on a preferred approach.

Based on this work, we have adopted these cost estimates for Options 1, 2 and 3, which we believe to represent thorough and reasonable cost estimates for the options based on the conceptual stage of design.

In the case of Option 4: Adaptive Phased Management, cost estimates have been developed for us by Golder Associates and Gartner Lee, using consistent estimating assumptions (www.nwmo.ca/assessments).

Table 4-12 Costs Estimates for Management Approaches

Management Approach	Total Cost (2002B$) (out to 350 years)	Total Cost (2002B$) (out to 1,000 years)	Present Value (Jan 2004 B$)
Option 1: Deep Geological Disposal in the Canadian Shield	16.2	16.3	6.2*
Option 2: Storage at Nuclear Reactor Sites			
Current Technology	17.6		2.3
New Above Ground Technology	25.7	68.4	4.4
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	46.9	3.8*
Cask/Vaults in Shallow Trenches	18.7		3.6
Casks in Rock Caverns	17.1	40.6	3.4*
Option 4: Adaptive Phased Management			
With Shallow Underground Storage	24.4	24.4	6.1*
Without Shallow Underground Storage	22.6	22.6	5.1*

JWO cost estimates are based on 3.7 million fuel bundles and an average reactor life of 40 years. Golder estimates are based on 3.6 million fuel bundles.
Estimates for Options 1, 2 and 3 out to 350 years were prepared by consultants for the Joint Waste Owners (www.nwmo.ca/costsummaries).
Estimates for Options 1, 2 and 3 out to 1,000 years were prepared by Golder Associates Ltd. and Gartner Lee Ltd. (www.nwmo.ca/assessments).
Estimates for Option 4 were prepared by Golder Associates Ltd. and Gartner Lee Ltd. (www.nwmo.ca/assessments).
* Present value calculations performed by Golder Associates Ltd. and Gartner Lee Ltd., are for 1000 year total estimates.
All remaining present value figures were taken from Joint Waste Owners cost estimates using 350 year total cost estimates.
Note: 1000 year cost estimates were produced from an illustrative sample of all possible management approaches, for comparative purposes only.

The *NFWA* requires that we take into account natural or other events that have a reasonable probability of occurring. As set forth in the Conceptual Design for Option 1: Deep Geological Disposal in the Canadian Shield, the design requires that testing, and on-going research and development work have as an objective designing and emplacing a containment canister that is capable of enduring a glaciation, within the time-frame in which the used fuel would continue to be a hazard.

Estimated rate of return on the trust funds maintained under subsection 9(1)

The cost estimates referenced above contain costs in billions of 2002 constant dollars and January 2004 present value billions of dollars. The present value calculation is based on a discount rate of 5.75 percent, which assumes a 3.25 percent real rate of return over a projected long-term average increase in the Ontario Consumer Price Index of 2.5 percent.

This data will be updated after the decision of the government on a management approach, as part of preparation of the first Annual Report required after this decision. Historical information available through Statistics Canada and the Bank of Canada show that the yields of Canada long bonds have exceeded CPI (Ontario) by approximately 4.8 percent over the past 25 years.

Life expectancy of the nuclear reactors of each nuclear energy corporation and of Atomic Energy of Canada Limited

The expected life of key components in CANDU reactors operating in Canada is a nominal 25 to 30 years and in some cases longer. The life of reactors is dependent on a decision to replace these components. Until such a decision is made, there is uncertainty in the life expectancy of all nuclear reactors.

If key components are replaced, it is assumed that reactor life will be 50 to 60 years. Given the uncertainty around reactor life, a conservative decision will be made on reactor life at the time of the government decision based on life extension programs in place or planned at that time. AECL will continue to generate a small amount of research reactor fuel in the future.

Estimated amounts to be received from owners of nuclear fuel waste, other than nuclear energy corporations and Atomic Energy of Canada Limited, in return for services of management of nuclear fuel waste.

At this time, current cost estimates do not include any allowances for the amount of nuclear fuel waste to be received from waste owners other than Ontario Power Generation Inc., Hydro-Québec, NB Power Nuclear and Atomic Energy of Canada Limited.

Should this situation arise, it is proposed that new waste owners would contribute an amount per fuel bundle generated, based on the full cost of the program on a present value basis. This would include payment for their share of fixed costs already incurred in order to become a member of the Joint Waste Owner (JWO) group of companies (currently comprised of OPG, HQ, NBP and AECL).

Respective percentage of the estimated total cost of management of nuclear fuel waste that is to be paid by each nuclear energy corporation and Atomic Energy of Canada Limited, and an explanation of how those respective percentages were determined.

The percentage of the estimated cost that is to be paid by each nuclear energy corporation and AECL will be largely based on projections of used fuel generated by each waste owner.

- For Option 1: Deep Geological Disposal, Option 3: Centralized Storage, and Option 4: Adaptive Phased Management
  - > The overall objective is to share actual costs of long-term management based on the number of fuel bundles. That is, each waste owner would pay equal costs for each fuel bundle subject only to owner specific costs such as transportation.

- For Option 2: Storage at Nuclear Reactor Sites
  - > Costs would be borne by the waste owner at each specific site. For shared facilities at a given location, costs would be shared based on waste fuel quantities at that location.

Current projected fuel bundles and percentages by waste owner to year-end 2005 are shown below in Table 4-13.

The percentage ownership by waste owner will differ from these in the long term due to differences in end-of-life projections.

In addition to CANDU fuel, AECL also has a small amount of research reactor fuel.

Trust fund contributions to be made by each producer will be reviewed as part of the Annual Report required following the decision by the federal government, with comprehensive reviews conducted every five years. Contributions will be continually adjusted to reflect improved projections of overall costs and number of fuel bundles to be produced by each waste owner.

18.2 / Financial Surety

Financial surety has the objective of determining what costs can reasonably be expected to occur over the life of a project, along with some contingency for unexpected events occurring, then designing a system that collects and protects enough funding to ensure that the entire cost of the project can be covered under a variety of social and economic circumstance and within the required time-frame. Financial surety can exist in many forms and generally includes utilizing a variety of financial instruments from secured assets and trust funds to government-supported guarantees.

Canada has a robust system of legal and regulatory oversight, covering all aspects of the nuclear industry. The standards that have been developed to provide financial surety for the long-term management of spent nuclear fuel share many elements of design and implementation with other nations around the world.

Table 4-13 Current Projected Fuel Bundles and Percentages by Waste Owners

Company	No. of bundles	Percentage of bundles
Ontario Power Generation Inc.	1,746,410	88.21
NB Power Nuclear	103,436	5.22
Hydro-Québec	99,245	5.01
Atomic Energy of Canada Limited	30,682	1.55
Total	1,979,773	100.0

Note: Number of fuel bundles based on 2005 year end projections

The previous section addressed one important component of financial surety – the financial guarantees required by the Canadian Nuclear Safety Commission. The Commission has required nuclear facility operators to provide evidence of financial guarantees as a condition of licensing. The guidelines used to determine the appropriateness of a financial guarantee are stated in the Commission's Regulatory Guide G-219, "Decommissioning Planning For Licensed Activities," 2000.

There are additional legislative and financial structures in place that also address financial surety concerning obligations and expected costs of the present and future spent fuel inventory.

The following legislation and regulations direct the level of financial surety that is required within Canada:

- The *Nuclear Safety and Control Act*, 1997;
- Canadian Nuclear Safety Commission Regulatory Guide, G-206, "Financial Guarantees For the Decommissioning of Licensed Activities" 2000;
- Canadian Nuclear Safety Commission Regulatory Guide, G-219, "Decommissioning Planning For Licensed Activities," 2000;
- The *Nuclear Fuel Waste Act*, 2002; and
- The *Nuclear Liability Act*.

The following list of topics covers both specific and general requirements that are addressed in legislation and regulations, with many areas being impacted by more than one statute or regulation. Areas addressed include:

- Methods for collecting and managing funds that will meet the cost estimate forecasts in an equitable manner and within reasonable time-frames;
- Methods for adjusting the rate and size of funds that are collected should circumstances change over time;
- Reasonable determinations of cost estimates, derived financial obligations and forms of surety provided;
- Contingency programs that will allow all financial obligations to be met even when unexpected events significantly impact the Canadian market;
- A reporting methodology to verify that appropriate financial practices are implemented and that on-going adjustments are made to both cost estimates and the financial guarantees to ensure they are accurate; and
- Setting limits on liability and insurance requirements for various licensed operations.

Trust Funds

Canada has developed legislation that specifically addresses the future financial obligations for managing spent fuel distinct from all other decommissioning costs. The *NFWA* administered by the Ministry of Natural Resources Canada, is the federal legislation that required the creation of the NWMO, and set out requirements for the establishment of trust funds for the long-term management of Canada's used nuclear fuel.

Nuclear Fuel Waste Act (*NFWA*) reference:

9. (1) Each nuclear energy corporation and Atomic Energy of Canada Limited shall maintain in Canada, either individually or jointly with one or more of the other nuclear energy corporations or Atomic Energy of Canada Limited, one trust fund with a financial institution incorporated or formed by or under an Act of Parliament or of the legislature of a province, except in the case of a nuclear energy corporation, a financial institution in relation to which the nuclear energy corporation beneficially owns, directly or indirectly more than ten percent of the outstanding shares of any given class of shares.

9. (2) The financial institution that holds a trust fund referred to in this section shall maintain in Canada all documents relating to that trust fund.

10. (1) Each body mentioned in this subsection shall, either directly or through a third party, no later than 10 days after the day on which this Act comes into force, deposit to its trust fund maintained under subsection 9(1) the following respective amounts:

(a) Ontario Power Generation Inc., $500,000,000;
(b) Hydro-Québec, $20,000,000;
(c) New Brunswick Power Corporation, $20,000,000; and
(d) Atomic Energy of Canada Limited, $10,000,000.

10. (2) Each body mentioned in this subsection shall in each year, either directly or through a third party, no later than the anniversary of the day on which this Act comes into force, deposit to its trust fund maintained under subsection 9(1) the following respective amounts:

(a) Ontario Power Generation Inc., $100,000,000;
(b) Hydro-Québec, $4,000,000;
(c) New Brunswick Power Corporation, $4,000,000; and
(d) Atomic Energy of Canada Limited, $2,000,000.

10. (3) subsection (2) ceases to apply on the day on which the Minister approves the amount of the deposit under paragraph 16(3)(a).

10. (4) Interest accumulates on any portion of a deposit not paid by the day referred to in subsection (1) or (2), at the prime rate plus two percent, calculated daily from the day referred to in subsection (1) or (2), as the case may be, to the day before the day of the deposit.

10. (5) Each body mentioned in subsection (1) or (2) shall, either directly or through a third party, deposit to its trust fund maintained under subsection 9(1), no later than 30 days after the date of the decision of the Governor in Council under section 15, the applicable amount referred to in subsection (1) or (2) plus an amount, if any, equal to the interest.

17. (1) Each nuclear energy corporation and Atomic Energy of Canada Limited shall, either directly or through a third party, deposit to its trust fund maintained under subsection 9(1) its respective deposit specified in the annual report

(a) if the Minister's approval under subsection 16(3) is not required, within 30 days after the annual report is submitted to the Minister under subsection 16(1); or
(b) if the Minister's approval under subsection 16(3) is required, within 30 days after the date of that approval.

17. (2) Notwithstanding subsection (1), the Governor in Council may, on request by a nuclear energy corporation made before the expiration of the 30 day period referred to in that subsection, authorize the nuclear energy corporation to defer by one year all or part of its deposit required by that subsection, if the Governor in Council is of the opinion that the public interest requires that the money be used instead to repair the damage caused by an event that is not attributable to the corporation and is extraordinary, unforeseen and irresistible.

Once a decision has been made by the federal government on the appropriate management approach for all nuclear waste owners, then the funding formula will allocate liabilities to each nuclear waste owner for their portion of the overall cost of the management approach. The funding formula, as presented in the NWMO's Annual Report, following a government decision on an approach, will be subject to Ministerial approval.

In accord with the requirements of the *NFWA*, Ontario Power Generation Inc. (OPG), Hydro-Québec (HQ), NB Power Nuclear (NBP), and Atomic Energy Canada Ltd. (AECL), each established an individual trust fund, that is held and managed by an independent third party. The trusts were established in 2002 in compliance with the *NFWA*.

Initial deposits as specified by the legislation have been made by all four bodies.

Subsequent deposits as specified have been made by each waste owner. As of November 15, 2004, the four corporations collectively had contributed $770 million. As of November 15, 2005, a further $110 million will be contributed through the annual provision, bringing the total to $880 million.

The *NFWA* specifies that the on-going contributions are to continue, at the present rate, until the first annual report on funding requirements is provided by us to the Minister of Natural Resources, after a decision has been made by the government on which management approach is to be implemented.

Safeguarding the Trust Funds

Individual waste owners are providing large sums of money to dedicated trust funds that will ensure that money is in place to implement the long-term management of used fuel. Experience in other countries has demonstrated the importance of safeguarding these large funds, so that they will be preserved for the intended purpose. In Canada, the *NFWA* built in explicit provisions that will ensure that these Trust Funds are maintained securely and used only for the intended purpose.

Nuclear Fuel Waste Act (*NFWA*) reference:
11. (1) Only the waste management organization may withdraw moneys from a trust fund maintained under subsection 9(1).

11. (2) The waste management organization may make withdrawals only for the purpose of implementing the approach that the Governor in Council selects under section 15 or approves under subsection 20(5), including avoiding or minimizing significant socio-economic effects on a community's way of life or on its social, cultural or economic aspirations.

11. (3) The waste management organization may make the first withdrawal only for an activity in respect of which a construction or operating licence has, after the date of the decision of the Governor in Council under section 15, been issued under section 24 of the *Nuclear Safety and Control Act*.

11. (4) If the Minister is of the view that the waste management organization has with drawn moneys from a trust fund contrary to subsection (2) or (3), the Minister may require the Minister's prior approval in respect of any future withdrawal from a trust fund by the waste management organization.

Nuclear Liability

The federal *Nuclear Liability Act* establishes the legal regime for liability for third party insurance and damage arising from nuclear accidents in Canada. The act creates an obligation for nuclear operators to prevent injury to health, or damage to property, from nuclear material at the facility, and while it is being transported until it enters another nuclear installation.

Used nuclear fuel is nuclear material and is therefore subject to the Act. In order to ensure that the liability for accidents involving used nuclear fuel in its possession is properly assigned, the NWMO will request separate nuclear installation status for any used fuel management facility it operates in future.

Operators of nuclear facilities are required to carry liability insurance up to $75 million. Claims beyond $75 million are determined by the federal government and paid out of general revenues.

Ongoing Financial Oversight: Ensuring Sufficiency of Trust Funds

Through its reporting practices, both as explicitly required within the act, and as a condition of attaining a CNSC licence to construct and operate a waste management facility, we will have an on-going obligation to assess the accuracy of the cost estimate for the selected management approach, and the sufficiency of funding contributions to cover cash flow obligations for the life of the project.

We will make regular determinations on the sufficiency of funding, changes to the cost estimate, or other material matters that would impact the provided financial surety and will provide this information to the CNSC, Natural Resources Canada and our Advisory Council.

The *NFWA* requires that specific reporting requirements be met, as outlined below. As part of the ongoing federal oversight that will continue, the *NFWA* provides for ministerial review and approval on the funding formula and proposed deposits by each waste owner.

<table>
<tr><td colspan="2">15. The Governor in Council, on the recommendation of the Minister, shall select one of the approaches for the management of nuclear fuel waste from among those set out in the study, and the decision of the Governor in Council shall be published in the Canada Gazette.</td></tr>
<tr><td colspan="2">Nuclear Fuel Waste Act (NWFA) References:</td></tr>
<tr><td>ANNUAL REPORTS</td><td>TRIENNIAL REPORTS</td></tr>
<tr><td>16. (1) The waste management organization shall, within three months after the end of each fiscal year of the organization, submit to the Minister a report of its activities for that fiscal year.

16. (2) Each annual report after the date of the decision of the Governor in Council under section 15 must include:
(a) the form and amount of any financial guarantees that have been provided during that fiscal year by the nuclear energy corporations and Atomic Energy of Canada Limited under the Nuclear Safety and Control Act and relate to implementing the approach that the Governor in Council selects under section 15 or approves under subsection 20(5);
(b) the updated estimated total cost of the management of nuclear fuel waste;
(c) the budget forecast for the next fiscal year;
(d) the proposed formula for the next fiscal year to calculate the amount required to finance the management of nuclear fuel waste and an explanation of the assumptions behind each term of the formula; and
(e) the amount of the deposit required to be paid during the next fiscal year by each of the nuclear energy corporations and Atomic Energy of Canada Limited, and the rationale by which those respective amounts were arrived at.

16. (3) The formula referred to in paragraph (2)(d) and the amount of each deposit referred to in paragraph (2)(e) are subject to the approval of the Minister when proposed in:
(a) the first annual report after the date of a decision of the Governor in Council under section 15 or subsection 20(5); and
(b) the first annual report after the issuance, under section 24 of the Nuclear Safety and Control Act, of a construction or operating licence for an activity to implement the approach that the Governor in Council selects under section 15 or approves under subsection 20(5);

16. (4) If the Minister
(a) is not satisfied that the formula referred to in paragraph (2)(d) will provide sufficient funds to implement the approach that the Governor in Council selects under section 15 or approves under subsection 20(5);
(b) is not satisfied that the amount of each deposit referred to in paragraph (2)(e) is consistent with the formula referred to in paragraph (2)(d).

the Minister shall refuse to give the approval referred to in subsection 3 and shall direct the waste management organization to revise the relevant portions of the annual report and submit the revised annual report to the Minster within 30 days.

23. (2) Every financial institution that holds a trust fund shall provide the Minister and the waste management organization, within three months after the end of each fiscal year of the trust fund, with financial statements relating to that trust fund, audited at its own expense by an independent auditor.</td><td>18. The annual report of the waste management organization for its third fiscal year after the fiscal year in which a decision is made by the Governor in Council under section 15, and for every third fiscal year after that, in this Act called the “triennial report”, must include:
(a) a summary of its activities respecting the management of nuclear fuel waste during the last three fiscal years, including an analysis of any significant socio-economic effects of those activities on a community's way of life or on its social, cultural or economic aspirations;
(b) its strategic plan for the next five fiscal years to implement the approach that the Governor in Council selects under section 15 or approves under subsection 20(5);
(c) its budget forecast for the next five fiscal years to implement the strategic plan;
(d) the results of its public consultations held during the last three fiscal years with respect to the matters set out in paragraphs (a) and (b); and
(e) the comments of the Advisory Council on the matters referred to in Paragraphs (a) to (d).</td></tr>
</table>

Financial Guarantees

The Canadian Nuclear Safety Commission (CNSC), operating under the *Nuclear Safety and Control Act, 1997* (*NSCA*), is the federal regulatory agency that oversees all licensing requirements for the site preparation, construction, operation, modification, decommissioning and abandonment of all Canadian nuclear facilities, including the licensing required for the management of spent fuel facilities.

The *NSCA* provides that the CNSC is responsible for issuing, amending, revoking and regulating all licenses in regard to all aspects of nuclear materials within Canada. Further, that any licence, can, within the authority of the Commission contain any term and condition that the Commission deems appropriate in fulfilling its mandate.

Sections 24(5) and (6) of the *NSCA* specifically address issues of financial guarantees. Section 24(5) states:

> A licence may contain any term or condition that the Commission considers necessary for the purposes of this Act, including a condition the applicant provide a financial guarantee in a form that is acceptable to the Commission.

Financial guarantees are provided by each nuclear waste owner and AECL in accordance with CNSC Regulatory Guide G-206, Financial Guarantees for the Decommissioning of Licensed Activities. These have been provided by all waste owners.

Financial guarantees provided by Ontario Power Generation, Hydro-Québec, NB Power Nuclear and Atomic Energy of Canada Limited are as follows:

Ontario Power Generation Inc.

Effective July 31, 2003, OPG provided the CNSC with a Decommissioning Financial Guarantee that included a guarantee associated with used fuel arising from the operation of OPG-owned facilities, including the facility leased by Bruce Power.

- The value of the used fuel guarantee required changes over time based on new generation of used fuel;
- The guarantee covers a five-year period to year-end 2007 and is updated annually by means of an annual report provided to the CNSC;
- For year 2005, the value of the guarantee for used fuel management is approximately $4.5 billion stated in present value as of January 1, 2005. The total guarantee provided to the CNSC covers management of nuclear waste and station/waste facility decommissioning; and
- The guarantee is satisfied by actual accumulation of funds within segregated funds under the Ontario Nuclear Funds Agreement (ONFA) between OPG and the Province of Ontario, the *NFWA* trust fund, and a provincial guarantee for the balance. The year 2005 total financial guarantee is approximately 88 percent funded by the segregated funds/trust fund with the balance of 12 percent guaranteed by the Province of Ontario.

Hydro-Québec

Hydro-Québec has provided to the CNSC a financial guarantee of $525 million stated in present value as of January 1, 2013.

- The guarantee is in the form of an expressed commitment of the Province of Québec to Hydro-Québec, which provides a continuous guarantee of payment until December 31, 2013. The guarantee covers both decommissioning and used fuel; and
- The total guarantee is made up of $205 million for decommissioning and $320 million for used fuel projected generated by the operation of Gentilly-2 until 2013.

NB Power Nuclear

NB Power Nuclear has provided a financial guarantee for the lifetime management of irradiated fuel projected to be produced to the end of Point Lepreau Generating Station's current Power Reactor Operating licence (December 31, 2005).

- The financial guarantee is based on the present value of future costs to manage this fuel on an incremental fee for service basis;
- In year 2003, the present value was calculated at $93.4 million;
- This amount was fully funded through $73.4 million in the used fuel fund and $20 million in the *NFWA* fund;
- At March 31, 2004 the used fuel fund contained $76 million and the *NFWA* fund contained $24 million.

Atomic Energy of Canada Limited

The AECL financial guarantee is in the form of an expressed commitment by the federal government to the CNSC. No specific dollar values are quoted in the commitment letter.

The annual report to the Minister will provide details on financial guarantees required by waste owners and how these guarantees have been provided by each waste owner for that fiscal year. The report will relate to implementing the approach selected by the government.

Cost estimates will be reviewed on an annual basis and updated where material changes have occurred and fully updated on a five-year cycle. The initial Annual Report will update the cost estimates to capture details of the selected approach. The budget forecast for the next fiscal year will be our budget for the coming year to move forward on the selected approach. Owner-specific costs related to ongoing storage at owner sites will be the responsibility of each waste owner's budget, and not the NWMO.

The proposed formula for the next fiscal year would cover the (i) ongoing annual costs plus (ii) program costs covered by the trust fund. Ongoing annual costs would be shared by all waste owners based in part on total fuel bundle quantities projected to be generated by each waste owner. At this time, ongoing costs are covered by a Membership Agreement between OPG, HQ and NBP. AECL may participate in the next phase of the program after 2005. Trust fund contributions would be based on fuel ownership projections by waste owner for shared costs and direct payment by waste owner for owner specific costs. Results would be covered under 16(2)(a) to (e) The amount of the deposit for the next fiscal year would be the result of applying the formula in section 16(2)(d) to the updated estimated cost and fuel generated, to arrive at the deposits required to the trust funds.

Upon submission of the first Annual Report following the decision of the government the Minister has the opportunity to approve the funding formula and the deposits. A further opportunity arises with the submission of the first Annual Report after the issuance of a construction or operating licence.

If approval is withheld, a re-submission will be made as directed by section 16(4) of the *NFWA*. The timing for contributions to the trust fund is based on annual report submissions and Minister approval requirements. The Annual Report is due three months after our fiscal year-end, and contributions within 30 days after that unless Minister approval is required which would prolong that period. This has particular application in the period between the initial section 10 contributions and initial contributions post-government decision.

PART FIVE NWMO Advisory Council Statement

How the Advisory Council of the Nuclear Waste Management Organization Intends to Fulfill its Mandate

NWMO Advisory Council Statement

Following is a statement by the Advisory Council, a body created in 2002 by the NWMO, consistent with the requirements of the *Nuclear Fuel Waste Act* (*NFWA*).

Under the Act, the Advisory Council has a legislative mandate to provide comments on the NWMO study. These comments are to be submitted to the Minister of Natural Resources Canada.

This statement outlines the approach the Council will take to produce a full analysis of the work of the NWMO, which will be published in the NWMO final report to the federal government, later this year. More details of the Council and its activities can be found on the NWMO website, http://www.nwmo.ca/advisorycouncil.

The nine-member Council includes Canadians knowledgeable in nuclear waste issues, and experienced in working with citizens and communities on a range of difficult public policy issues. Appendix 1 outlines the Council membership. For information about Advisory Council members please see the NWMO website, www.nwmo.ca/acmembers.

How the Advisory Council of the Nuclear Waste Management Organization Intends to Fulfill its Mandate

January 22, 2005

The Legislation

The *Nuclear Fuel Waste Act* (*An Act respecting the long-term management of nuclear fuel waste*) aims:

> "to provide a framework to enable the Governor in Council to make, from the proposals of the waste management organization, a decision on the management of nuclear fuel waste that is based on a comprehensive, integrated and economically sound approach for Canada."

The Act requires the waste management organization, at the end of three years, to submit a study setting out its proposed approaches for the management of nuclear fuel waste and to recommend one of those approaches for adoption.

The Act also establishes an Advisory Council charged with the responsibility of examining the study and giving written comments on it to the Nuclear Waste Management Organization (NWMO). The NWMO, for its part, is required to submit those comments to the Minister along with its study. Section 12 of the legislation, which discusses the study, imposes an obligation on the Advisory Council to comment on the approaches for the management of nuclear fuel waste contained in the study. While it does not specifically require the Council to comment on the NWMO's recommendations, that requirement can be reasonably inferred from the obligation to comment on 'the study' and 'the approaches', which will of course contain the recommendations.

The NWMO Study

The NWMO's study is obliged to examine at least the following approaches: deep geological disposal; storage at nuclear reactor sites; and centralized storage, either above or below ground. The examination of other approaches is not precluded by the legislation. For each proposed approach the NWMO must include the following:

- Detailed technical description
- Specification of an economic region for implementation
- A comparison of benefits, risks and costs with those of the other approaches
- The associated ethical, social and economic considerations
- A description of the waste management services to be offered by the NWMO
- An implementation plan (description of activities, timetable, means of avoiding or minimizing significant socio-economic effects on a community's way of life or its social, cultural or economic aspirations, and a program of public consultation)
- A summary of comments arising out of consultation with the general public and with aboriginal peoples
- A financial formula to cover the costs
- A cost-sharing formula allocating costs to waste producers
- The form and amount of any financial guarantees provided by the nuclear energy corporations

Finally, the study is required to recommend one of the approaches thus described.

This, then, is the nature of the study on which the Advisory Council is obliged to provide written comments.

The Advisory Council's Approach

The legislation creating the Nuclear Waste Management Organization and its Advisory Council is very broad. Within the framework of the legislation, we – as members of the Advisory Council – see our responsibilities in the following way.

As part of our obligation to examine and give written comment on the NWMO's study at the end of the three-year period, we believe it is appropriate for the Council to learn about the ongoing work of the NWMO and for the Council to express its views about that work as it is being done. Accordingly, members of the Advisory Council decided at its establishment in October 2002 to meet regularly with NWMO management and to offer ongoing advice about the conduct of their undertaking. To date we have had 13 formal meetings with NWMO staff as well as four meetings with members of the NWMO Board of Directors. Our work is recorded in the minutes posted on the Organization's web site. At the end of the three-year process, we intend to post the Tracking Matrix we used to assist us in tracking our activities and in supporting the preparation of our written comments on the NWMO study.

In fulfilling its legislative obligations, the Advisory Council will offer written comments and observations on the work and study of the NWMO.

The Council will review and comment on the comprehensiveness of the NWMO study. Did it properly consider all of the available reasonable alternative approaches? Did it thoroughly cover the three required options? Does the report adequately address all of the elements stipulated in the legislation with respect to each of the options?

The Council will review and comment on the fairness and balance of the study. Has the analysis supporting the report given appropriate weight to all relevant evidence, neglecting none of significance? Does the study give adequate consideration to diverse points of view and recognize the interests of minority positions? Is there any evidence of bias or partiality in the analysis and recommendations? Does the recommended policy choice emerge logically out of the careful and considered weighing of the pros and cons of the respective alternatives?

The Council will review and comment on the integrity of the NWMO process. Did the process provide sufficient opportunity for public engagement? Were aboriginal people, concerned stakeholders, and potentially or actually affected communities given real opportunities to make their views known? Were these views responsibly considered and appropriately taken into account? Were available sources of expertise and specialized experience sought out and utilized effectively? Were 'state of the art' processes of public consultation, ethical reflection, socio-economic analysis, technical and scientific study, financial forecasting, and impact assessment employed? Was international comparative experience adequately considered?

The Council will review and comment on the transparency of the process. Did the NWMO make its plans and timetable clear to the interested public? Did it share information with citizens in a timely fashion so that they had the capacity to participate effectively in the process? Did it simplify technical data and complex scientific matters honestly and effectively to assist in the development of public understanding? Did the Organization allow sufficient time for comment, input and reaction from stakeholders and the general public?

In conclusion, there is one other issue that requires comment. The legislation is silent on the question of the quantity of nuclear fuel waste that is to be managed by the recommended approach. In its examination and selection of management approaches, the NWMO will have to address the matter of capacity, and therefore of quantity. How much nuclear waste is it assumed that any given management approach will be able to handle? This question is tied to the larger policy question of the future of nuclear energy in Canada.

The Advisory Council would be critical of an NWMO recommendation of any management approach that makes provision for more nuclear fuel waste than the present generating plants are expected to create, unless it were linked to a clear statement about the need for broad public discussion of Canadian energy policy prior to a decision about future nuclear energy development. The potential role of nuclear energy in addressing Canada's future electricity requirements needs to be placed within a much larger policy framework that examines the costs, benefits and hazards of all available forms of electrical energy supply, and that framework needs to make provision for comprehensive, informed public participation.

Appendices

APPENDIX 1 / NWMO PROFILE

The Nuclear Waste Management Organization (NWMO) was established by Canada's nuclear electricity generators following passage of the *Nuclear Fuel Waste Act* in 2002. The legislation provides a framework for the Government of Canada to make a decision on the long-term management of used nuclear fuel. It requires the NWMO to investigate and develop an approach and present its recommendations to the government by November 2005.

At a minimum, three approaches must be studied. They are: deep geological disposal, centralized storage – above or below ground, and continued reactor site storage. The NWMO may consider other technical methods. Each approach studied must be fully described including risks, costs and benefits. Implementation plans must also be developed.

The NWMO is committed to developing collaboratively with Canadians a recommendation that is socially acceptable, environmentally responsible, technically sound, and economically feasible. Recognizing that it is not enough to invite people to participate in developing a recommendation, the NWMO has sought to involve citizens in shaping the decision-making process itself. It has developed an iterative study plan, evolving in response to ongoing dialogue. The plan is built on three milestone documents which allow people to learn together with the NWMO and see its thinking at every stage.

The intent is that there will be no surprises when the final recommendations are made.

The NWMO has an independent Advisory Council whose written comments on its study of proposed approaches will be made public. Advisory Council members include: the Honourable David Crombie (Council Chairman), David Cameron, Helen Cooper, Gordon Cressy, Fred Gilbert, Eva Ligeti, Derek Lister, Donald Obonsawin and Daniel Rozon.

The NWMO Board of Directors is currently composed of representatives of the major owners of used nuclear fuel: Ontario Power Generation Inc., Hydro-Québec and NB Power Nuclear. Members of the Board of Directors include: Ken Nash, Laurie Comeau, Fred Long, Adèle Malo and Michel Rhéaume.

Elizabeth Dowdeswell is President of the NWMO.

A link to the *Nuclear Fuel Waste Act* on the Government of Canada website is available from the NWMO website at: www.nwmo.ca/nuclearfuelwasteact.

APPENDIX 2 / NATURE OF THE HAZARD

Over the course of its study, the NWMO has assembled a number of facts about the nature of the hazard posed by used nuclear fuel. We also convened a workshop involving 16 experts and other persons knowledgeable on various technical, environmental, health, social and ethical aspects of used nuclear fuel to further discuss this issue. The information assembled by the NWMO, and excerpts from the statement produced by the workshop are described here.

1. Canadian Used Nuclear Fuel – Characteristics

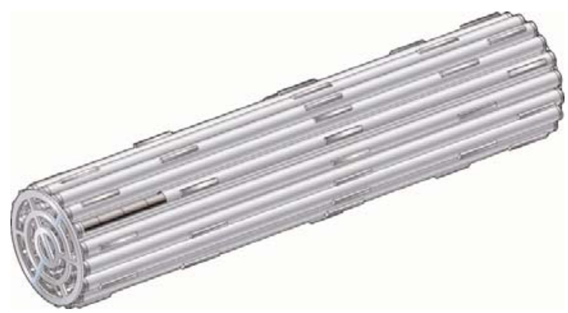
In Canada, used nuclear fuel consists primarily of used CANDU fuel which is generated at commercial nuclear power reactors in Ontario, Québec and New Brunswick. In addition, there are very small quantities of used fuel from research and isotope-producing reactors in Canada (*Asking the Right Questions?*, NWMO Discussion Document 1 or DD1) (NWMO 2003). In many respects, these other nuclear fuel types are similar to the commercial nuclear fuels and they are commonly used at other research facilities around the world. Also, some of the Canadian nuclear utilities have proposed slight modifications to the composition of the nuclear fuel (e.g., slightly enriched uranium). Nevertheless, all of the used nuclear fuel in Canada will need to be addressed in an appropriate manner during implementation of a long-term management approach.

In a nuclear-powered electricity generating station, heat is produced by fission, which occurs in a fuel bundle when a neutron is absorbed by certain heavy elements (such as uranium-235 or plutonium-239). The characteristics and radionuclide content of used CANDU fuel for long-term management has been described in several reports such as AECL (1994) and Tait et al. (2000).

In the CANDU system used in Canada, each fuel bundle contains about 19 kg of natural uranium, in the form of high-density uranium dioxide ceramic pellets. These pellets are sealed inside zirconium alloy tubes, about 0.5m long, arranged in a circular array 10 cm in diameter (see Figure A2-1). Heat is removed by passing liquid heavy water over the many bundles in the reactor. In turn, the heavy water coolant passes through boilers which transfer the heat to ordinary water, producing steam. The cooled heavy water is then pumped through the reactor again in a closed loop in order to retain the heavy water. The steam from the boilers drives a turbine generator, producing electricity.

When an atom is split and neutrons are released, one neutron goes on to split another atom, and so on, keeping the nuclear reaction going. Another 1.3 neutrons (on average) are absorbed by the non-fissionable materials in the fuel and the reactor core. As the process continues, the concentration of fission products increases until their neutron absorption capacity becomes so large that the nuclear reaction begins to be impeded. At this stage, after about 18 months, the fuel is removed both because of the partial depletion of the fissile material as well as the build-up of neutron-absorbing fission products and actinides.

Figure A2-1 CANDU Fuel Bundle



Unirradiated CANDU fuel consists primarily of ceramic uranium dioxide pellets. CANDU fuel is composed of natural uranium which is approximately 99.28 percent uranium-238 and 0.72 percent uranium 235 (NWMO 2003). Irradiated or used CANDU fuel consists of approximately 98.58 percent uranium-238, 0.23 percent uranium-235, 0.27 percent plutonium-239 and hundreds of other radioactive fission products and minor actinides (see Table A2-1).

When the used fuel is removed from the reactor, it is highly radioactive, although the radioactivity depends on the burn-up in the reactor. The radioactivity decreases substantially with time due primarily to the decay of short-lived radionuclides. The radioactivity of used fuel (Bq/kg U) decreases to about one percent of its initial value after one year, decreases to about 0.1 percent after 10 years and decreases to about 0.01 percent after 100 years (AECL 1994). After about one million years, the radioactivity in used fuel approaches that of natural uranium (AECL 1994; NWMO 2003; McMurry et al. 2004).

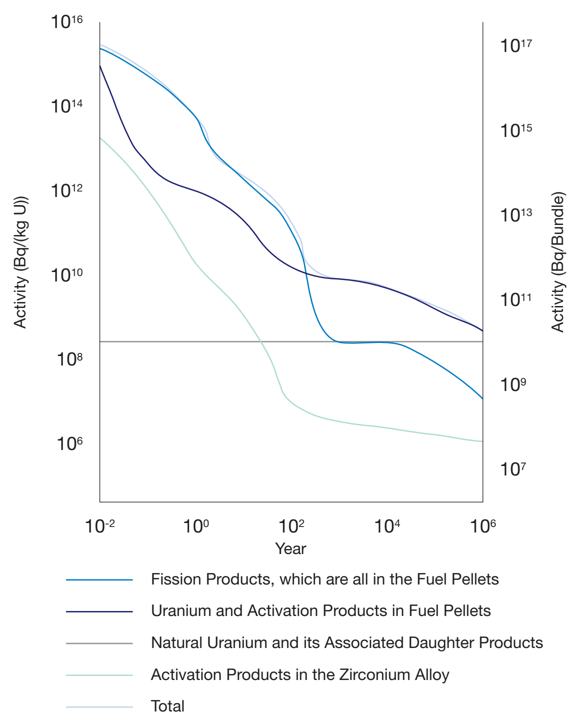
The total radioactivity of a used CANDU fuel bundle as a function of time out of reactor is illustrated in Figure A2-2. Over a million-year time period, the activity of used fuel drops by about six orders of magnitude. The total radioactivity of used fuel then becomes comparable to the total radioactivity associated with natural uranium ore deposit. This is considered by some people to be a useful benchmark. However, radiotoxicity considerations must also be considered (see following sections on regulations and radiotoxicity).

Much of the emitted radiation is absorbed as heat by the fuel and surrounding materials. When a bundle is discharged from the reactor, the heat output is about 37,000 watts (AECL 1994). The heat output drops to 73 watts after one year, five watts after 10 years and one watt after 100 years. After about one million years, the decay heat from used fuel approaches that of natural uranium and its associated products (AECL 1994).

Table A2-1 Composition of Fresh and Used CANDU Nuclear Fuel

COMPONENT	COMPOSITION OF FRESH FUEL, %	COMPOSITION OF USED FUEL, %
Uranium-235	0.72	0.23
Uranium-236	0	0.07
Uranium-238	99.28	98.58
Plutonium-239	0	0.25
Plutonium-240	0	0.10
Plutonium-241	0	0.02
Plutonium-242	0	0.01
Fission products	-	0.74

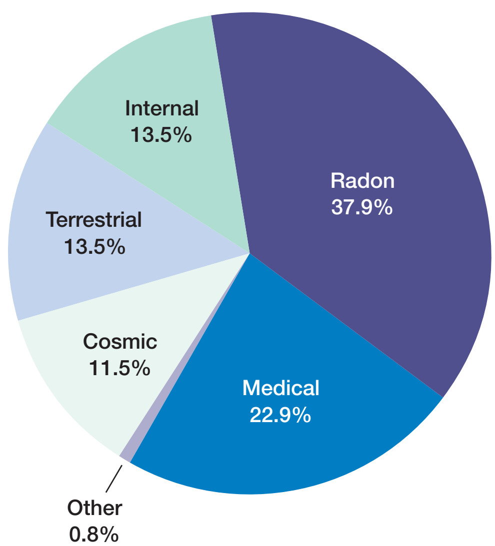
Figure A2-2 Total Activity of Used CANDU Fuel as a Function of Time Out of Reactor



2. Canadian Radiation Protection Regulations and Licences

The Canadian Nuclear Safety Commission (CNSC) has set an annual radiation dose limit of 1 mSv/a for members of the public (Government of Canada 2000). For comparison, the average annual background radiation dose to members of public in Canada is approximately 3 mSv (Sutherland 2003). The typical sources of radiation exposure are illustrated in Figure A2-3. They include radon gas from the earth's crust, radioactivity in the air, food and water, cosmic radiation and medical exposures such as dental x-rays.

Figure A2-3 Sources of Background Radiation Exposure in Canada



In public radiological safety analyses, the critical benchmark is the CNSC dose limit of 1 mSv/a. As well, the average annual background radiation exposure of 3 mSv/a is sometimes used as a point of reference in safety assessments (e.g., Gierszewski et al. 2004).

For nuclear energy workers over a five year period, the annual radiation dose limit is 20 mSv/a.

The CNSC's Radiation Safety Data Sheet for uranium-238 indicates that a licence would be required for possessing more than 1 x 10^7 Bq of uranium-238 in a non-dispersible form (see CNSC website at www.nuclearsafety.gc.ca). Given a specific activity for uranium-238 of 1.2 x 10^7 Bq/kg, a CNSC licence would be required to possess more than approximately one kg of uranium.

3. Main Hazards

3.1 Radiotoxicity and Chemical Toxicity of Used Nuclear Fuel

Used nuclear fuel is a potential source of both external radiation and internal exposure to humans and the natural environment. The health effects and dose rate factors from exposure to ionizing radiation have been studied over the years and documented in numerous publications such as BEIR (1990), ICRP (1991) and UNSCEAR (2000), and recently summarized in Sutherland (2003). There is on-going debate on the potential biological effects of radiation on humans and non-human biota, health risks and dose models associated with low and high doses, low and high dose rates (e.g., see ECRR 2003). There is also on-going debate on the potential benefits from low doses of radiation (hormesis), the apparent conservatism of the linear-no-threshold hypothesis for calculating risk and whether or not regulations set to protect humans are sufficient to protect non-human biota. While these debates will undoubtedly continue for some time, there is general agreement that radiation exposure needs to be controlled and regulated to protect humans and the environment.

The radiotoxicity of used nuclear fuel depends on the exposure pathway, the dose associated with each radionuclide and the time out of reactor. A common radiotoxicity index is based on the dose or risk calculated from ingestion (Mehta et al. 1991; OECD 2004). Similarly, drinking water guidelines are usually based on the water ingestion pathway (2 L/day), dose conversion factors for individual radionuclides and a dose limit set at 10 percent of the public dose limit (0.1 mSv/a). The Health Canada *Guidelines for Canadian Drinking Water Quality* were recently published in April 2004.

The Health Canada maximum acceptable concentration (MAC) for selected radionuclides which are important in used nuclear fuel is listed in Table A2-2. The principal chemical in used fuel is uranium and the MAC for uranium is limited by its chemical toxicity value of 0.02 mg/L which corresponds to a radionuclide concentration of about 0.5 Bq/L.

The radiotoxicity analysis for used CANDU fuel suggests that this material is a potential internal exposure health risk for more than one million years (Mehta et al. 1991; AECL 1994).

Similar analysis for used pressurized water reactor fuel (PWR) with enriched uranium-235 suggests

Table A2-2 **Canadian Drinking Water Guidelines – Maximum Acceptable Concentration (Ref. Health Canada, April 2004)**

RADIONUCLIDE	HALF LIFE (years)	INGESTION DOSE CONVERSION FACTOR (Sv/Bq)	MAC (Bq/L)
Uranium-235	704,000,000	3.8×10^{-8}	4[a]
Uranium-238	4,470,000,000	3.6×10^{-8}	4[a]
Plutonium-239	24,100	5.6×10^{-7}	0.2
Radium-226	1,600	2.2×10^{-7}	0.6
Cesium-137	30.2	1.3×10^{-8}	10
Carbon-14	5,730	5.6×10^{-10}	200
Iodine-129	16,000,000	1.1×10^{-7}	1

[a] Note, the MAC for uranium based on chemical toxicity is 0.02 mg/L or about 0.5 Bq/L.

that the radiotoxicity of used fuel becomes equal to the equivalent uranium ore after about 130,000 years (IAEA 2004). Other analysis suggests the time period is between 500,000 and one million years (OECD 2004). (*Note, due to enrichment of uranium-235 in light water reactor (LWR) fuel from 0.72 percent to up to five percent, one tonne of PWR fuel can be derived from about seven tonnes of uranium ore)*.

3.2 External Radiation from Used Nuclear Fuel

The external radiation field from a CANDU bundle depends on burn-up, time out of reactor and exposure distance from the fuel, which is typically measured from 0.3 to one metre from the source (Sutherland 2003). The external radiation fields for various fuel ages for an average burn-up of 7,800 MW days per tonne of uranium were taken from Sutherland (2003) and are listed in Table A2-3. The exposure time to reach the public radiation dose limit of 1 mSv/a is also given.

The analysis in Table A2-3 indicates that at 50 years, the external radiation dose from unshielded used nuclear fuel would present a significant health risk. At a dose rate of 1,150 mSv/h, unshielded nuclear fuel would give a potentially fatal dose of 5 Sv after about four hours of exposure. While the external radiation from used fuel declines rapidly with the passage of time, it could still be considered significant from a public dose perspective far into the future since exposure to million-year old fuel (or unirradiated fuel for that matter) could potentially reach the public dose limit of 1 mSv/a after about 110 hours.

Table A2-3 **External Radiation from Used CANDU Fuel as a Function of Time**

AGE OF USED CANDU FUEL (years)	UNSHIELDED EXTERNAL RADIATION FIELD AT 0.3 m (mSv/h)	EXPOSURE TIME TO REACH PUBLIC DOSE LIMIT OF 1 mSv/a
50	1,150	3 seconds
100	360	10 seconds
200	37	97 seconds
500	0.82	1.2 hours
1,000,000	0.009	110 hours

4. Longevity

Based on the above discussion, one could conclude that uranium ore, fresh nuclear fuel or million-year old used nuclear fuel would be a potential external exposure health risk if left uncontrolled at the surface. (The internal exposure pathways would likely be more restrictive).

Workshop Statement

A workshop involving 16 experts and other persons knowledgeable on various technical, environmental, health, social and ethical aspects of used nuclear fuel addressed the question "What is the nature of the hazard from used nuclear fuel." The workshop was held at the NWMO office on February 10, 2005. The full workshop report and final statement (including dissenting views) are available on the NWMO website (www.nwmo.ca/hazard).

Inherent Hazard

Hazard can be considered generally as a source of danger or a possibility of being harmed. The inherent hazards of used nuclear fuel are primarily its radio-toxicity and its chemical toxicity.

Used nuclear fuel is inherently hazardous to human health and the environment. Maximum hazard exists in the short term, and while it does diminish over time, for practical purposes some hazard remains for an indefinite time. The concept of indefinite time is in keeping with the premises of traditional knowledge and the need to ensure the health of all living beings. It reflects a recognition that there is scientific uncertainty.

Pathways

The radiological hazard inherent in used nuclear fuel can negatively impact the health of humans, other organisms and ecosystems if it enters into the environment. It can then have impacts through external exposure to the body, or through internal exposure by lesions, ingestion or inhalation. The chemical hazard inherent in used nuclear fuel can impact humans, other organisms and ecosystems through dispersal and uptake into living organisms. Radio-toxicity and chemical toxicity depend on dose received.

The main potential pathways for internal exposure are through groundwater flow and subsequent entry into the food chain. A potential pathway for both external and internal exposure is through airborne transport of material.

Control and Protection

Used nuclear fuel needs to be contained and isolated as a response to the hazard it poses.

There remain different scientific interpretations of the health impact of low doses and dose rates of ionizing radiation. While experts differ over what may constitute a safe level of radiation exposure, it is consistent with international practice to act, in a conservative manner, as if there are health risks from any exposure to radiation.

Some experts say it may be useful to study the characteristics of natural uranium deposits to ensure long-term protection of life from the hazards of used nuclear fuel.

There is an established international system for radiation protection to regulate radiation exposure resulting from human activity. This has been used for several decades to protect workers and the public.

Security

Security is required for used nuclear fuel because of the possibility that saboteurs could try to defeat the security measures of facilities and use the material to cause harm to people and the environment. Security concerns also relate to the diversion of used nuclear fuel toward the making of weapons.

Regulation, Standards and Oversight

Any approach for long-term management of used nuclear fuel will need to provide confidence that its implementation will meet or exceed regulatory requirements established by Canadian authorities, including the Canadian Nuclear Safety Commission, and it should be consistent with internationally recognized approaches. Canadian regulations generally follow international practices but Canadian law takes precedence.

Uncertainty

Much is known about the hazard associated with used nuclear fuel and its implications for long-term management approaches. However, given the long time periods involved, there are limitations to our knowledge and uncertainties associated with the environmental and human activity aspects of management approaches. A precautionary approach is appropriate.

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APPENDIX 3 / ADAPTIVE PHASED MANAGEMENT TECHNICAL DESCRIPTION

1. Introduction

The Nuclear Waste Management Organization (NWMO) is evaluating options for the long-term management of Canada's used nuclear fuel. It has examined the three options identified in the *Nuclear Fuel Waste Act (NFWA) (An Act Respecting the Long-Term Management of Nuclear Fuel Waste)* which was brought into force in November 2002:

(1) Deep geological disposal in the Canadian Shield;
(2) Storage at nuclear reactor sites; and
(3) Centralized storage, either above or below ground.

Conceptual designs and cost estimates have been prepared by consultants for the Joint Waste Owners (JWO) (Ontario Power Generation Inc., Hydro-Québec, NB Power Nuclear and Atomic Energy of Canada Limited) for the three options and the associated transportation systems. These reports are available on the NWMO website (www.nwmo.ca/conceptualdesigns). (For example, see Cogema 2003; CTECH 2002; CTECH 2003a; CTECH 2003b).

The three options for long-term management of used fuel have undergone detailed evaluation by the NWMO Assessment Team (Ben Eli et al. 2004) and by Golder/Gartner Lee (2005). The three options were also outlined in the NWMO's Second Discussion Document *Understanding the Choices* (NWMO 2004) and were the subject of extensive cross-country discussion and dialogue with Canadians in the Autumn 2004. What we found was each option has strengths, but each option has limitations as well.

From the numerous NWMO's meetings, presentations, dialogue sessions and input to our website, it is becoming clear that the three approaches outlined in the *NFWA* do not capture the necessary features and attributes of a preferred management approach for used nuclear fuel in Canada. There were suggestions that the NWMO should consider a fourth management approach which would select the best features of the three approaches in the *NFWA* and implement them in a staged or phased manner over time (DPRA 2005).

Canadians have told us that the overarching objective for managing used nuclear fuel must be to protect humans and the environment. Therefore, our overall goal is to effectively contain and isolate used nuclear fuel for all time while to ensuring that it is managed safely and securely at all times. A long-term management approach which is based on containment and isolation of used fuel is consistent with the draft regulatory guidance provided by the Canadian Nuclear Safety Commission (CNSC) for assessing long-term safety of radioactive waste management (CNSC 2005).

We plan to achieve this overall goal is by implementing an adaptive risk management approach based on centralized containment and isolation of Canada's used nuclear fuel deep underground. At all times throughout the three major phases the used fuel will be safe, secure, monitored and retrievable. Containment of used fuel will be achieved through a robust system of engineered barriers and isolation of used fuel will be achieved through a combination of institutional controls and natural barriers.

The features of a phased management approach are described in further detail in this report.

A staged approach to concept implementation reflects both the complex nature of the task and the very long duration of the activities. It also reflects the desire by many stakeholders to proceed by cautious steps with due regard to technical issues and social acceptance.

The NWMO has developed a high-level description of a **Fourth Option** which can be called **Adaptive Phased Management**. We believe that this approach addresses many of the issues that Canadians have identified during the NWMO study process and provides genuine choice, flexibility and options for long-term care of Canada's used nuclear fuel. This report outlines a general illustrative technical description of Adaptive Phased Management which can be used for conservative planning and cost estimating purposes.

2. Technical Description of Adaptive Phased Management

2.1 Three Phases of Implementation

Following a decision by the Government of Canada on the preferred approach for long-term management of Canada's used nuclear fuel, the NWMO would begin implementation of an adaptive phased management approach starting in Year 01. In Table A3-1, we summarize the three major phases of implementation.

Table A3-1 Three Phases of Adaptive Phased Management

PHASE	
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; Continue engagement with regulatory authorities to ensure pre-licencing work will be suitable for the subsequent licencing processes; 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; Initiate licencing process, which triggers the environmental assessment process under the *Canadian Environmental Assessment Act*; 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; Develop and certify transportation containers and used fuel handling capabilities; 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 postclosure monitoring of the system.

2.2 Overall Schedule for Implementation

Each of the three phases of adaptive phased management has many activities and decision points. While we do not know the precise duration of these activities or the outcome of future decisions in the approach, we can provide an indication of a representative schedule for implementation based on the conceptual design work and previous analyses of the three previous options for used fuel management (Cogema 2003; CTECH 2002; CTECH 2003a; CTECH 2003b). The illustrative overall schedule with some of the key activities and assumed decisions in each phase are listed in Figure A3-1.

Our illustrative schedule includes a number of key decisions over the next several decades and beyond. In Figure A3-1, we highlight the key activities and decisions which must be made before proceeding to the next step of concept implementation. This aspect of the approach provides Canadians with genuine choice and the opportunity for the public and other stakeholders to participate in concept implementation including participation in the decision-making process.

2.3 Phase 1: Preparing for Central Used Fuel Management

This phase sets the necessary building blocks for establishing the necessary facilities and infrastructure for long-term management of used fuel. While much has been done to advance the technology for used fuel management in Canada, clearly more research and development work needs to be completed. Our approach will enable us to take the time required to gain greater certainty in the performance of used fuel storage, transportation and isolation technologies, and Canadians will have the opportunity to participate in the radioactive waste management programs in other countries with similar concepts and geographical features.

We will put the necessary effort into gaining public confidence in the safety and security of the approach.

Locating a Central Site for Used Fuel Management

Based on international siting experience in Finland and Sweden, and the conceptual design studies developed for the long-term management options in Canada, we expect that it will take about 10 years to complete the siting feasibility studies and locate a preferred site for long-term management of used fuel. It will then take another 10 years to complete the detailed site characterization, safety analyses, complete the environmental assessment and obtain a Site Preparation Licence for shallow underground rock cavern storage, an underground research laboratory (URL) and a deep geologic repository at the central site. Construction Licences for these facilities would follow at a later time. Public and other stakeholder involvement will be important during the siting process and the environmental assessment and licensing activities.

If a decision is made to build the central storage facility sometime around Year 20, we are planning for 10 years to construct the surface handling facilities and the shallow rock caverns and to construct the underground research laboratory at the central facility. An Operating Licence for shallow rock cavern storage would be obtained by Year 30.

Therefore, for planning and cost estimating purposes, we have indicated about 30 years after Government of Canada decision for locating a central site and building related facilities. It may take longer. It may happen sooner. However, we consider that three decades is a reasonable time period based on international experience.

Siting of a long-term used fuel management facility will be based on the principle of voluntarism. NWMO will seek a willing host community for any facility that may be required, for example, a community with geomedia suitable for shallow underground storage and for a deep geologic repository. Examples of suitable geomedia in Canada may include host rock formations such as the crystalline rock of the Canadian Shield (AECL 1994) and the Ordovician sedimentary rock basins (Mazurek 2004). In order for a site to be acceptable, it would need to address scientific and technical factors to ensure that any facility built is capable of protecting us and future generations, other life-forms and the biosphere as a whole into the indefinite future.

Potentially suitable siting areas for a central used fuel management facility are illustrated in Figure A3-3.

Figure A3-1 **Activity Flow Chart for Adaptive Phased Management**

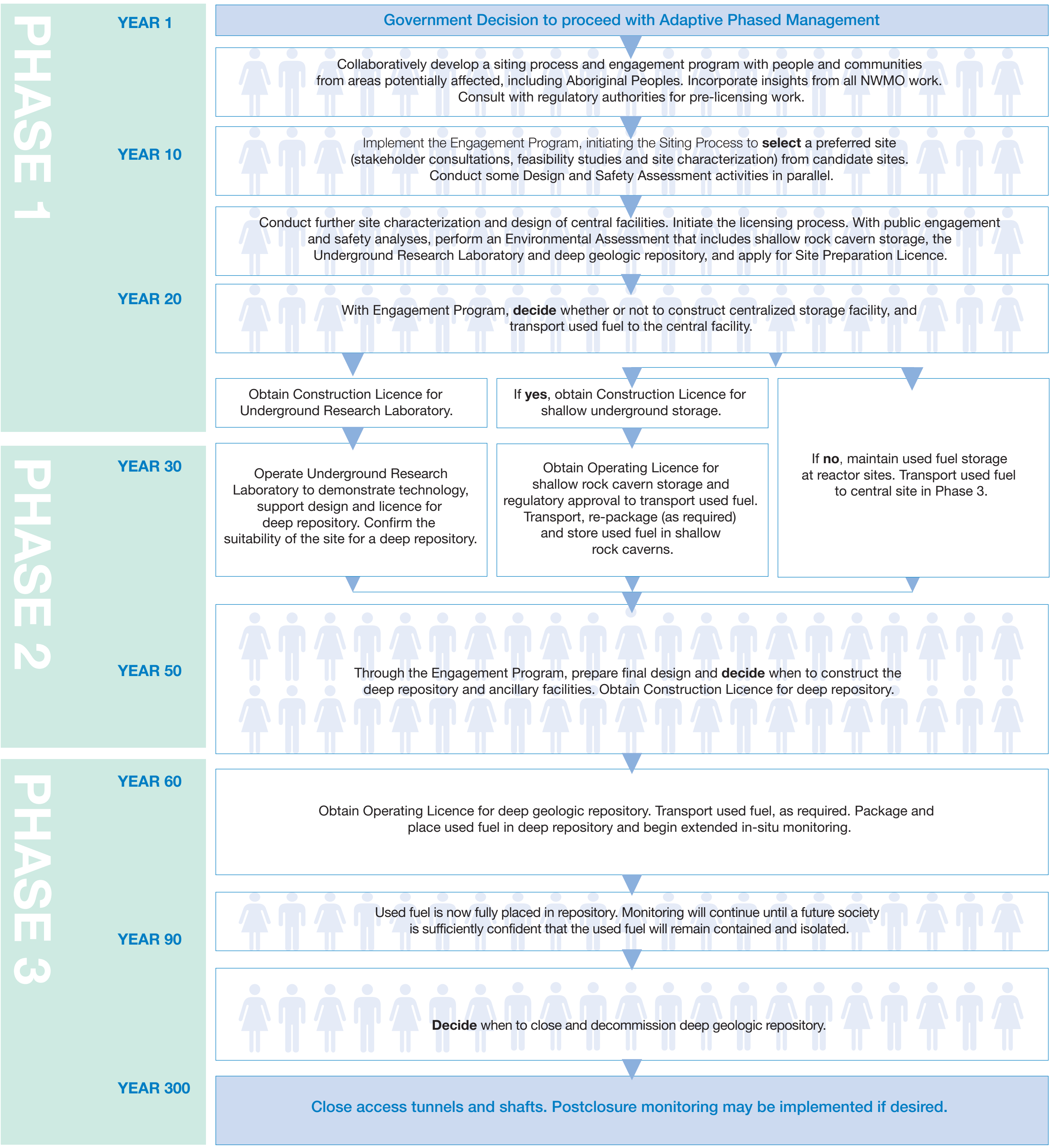
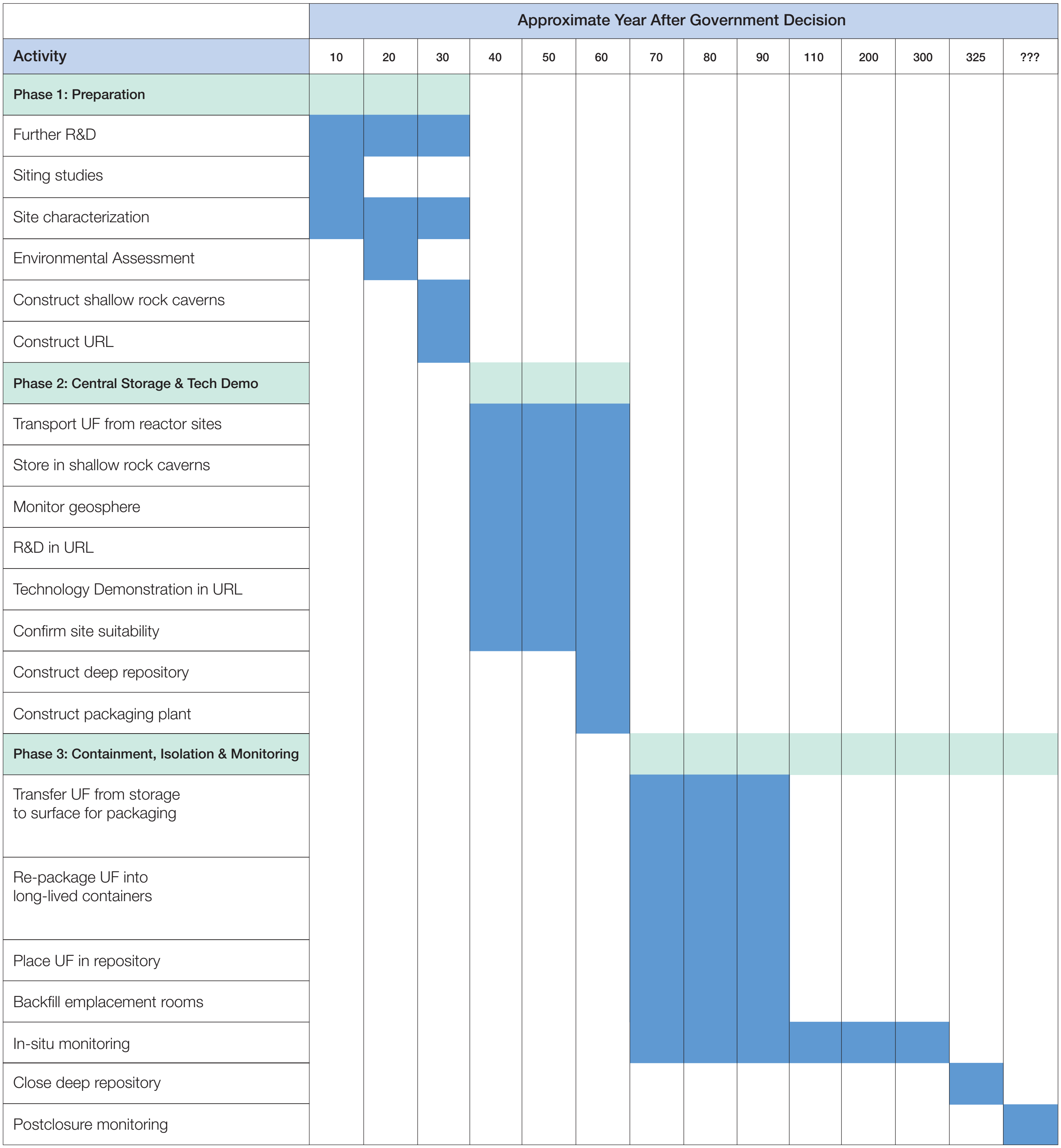


Figure A3-2 Illustrative Overall Schedule for Adaptive Phased Management



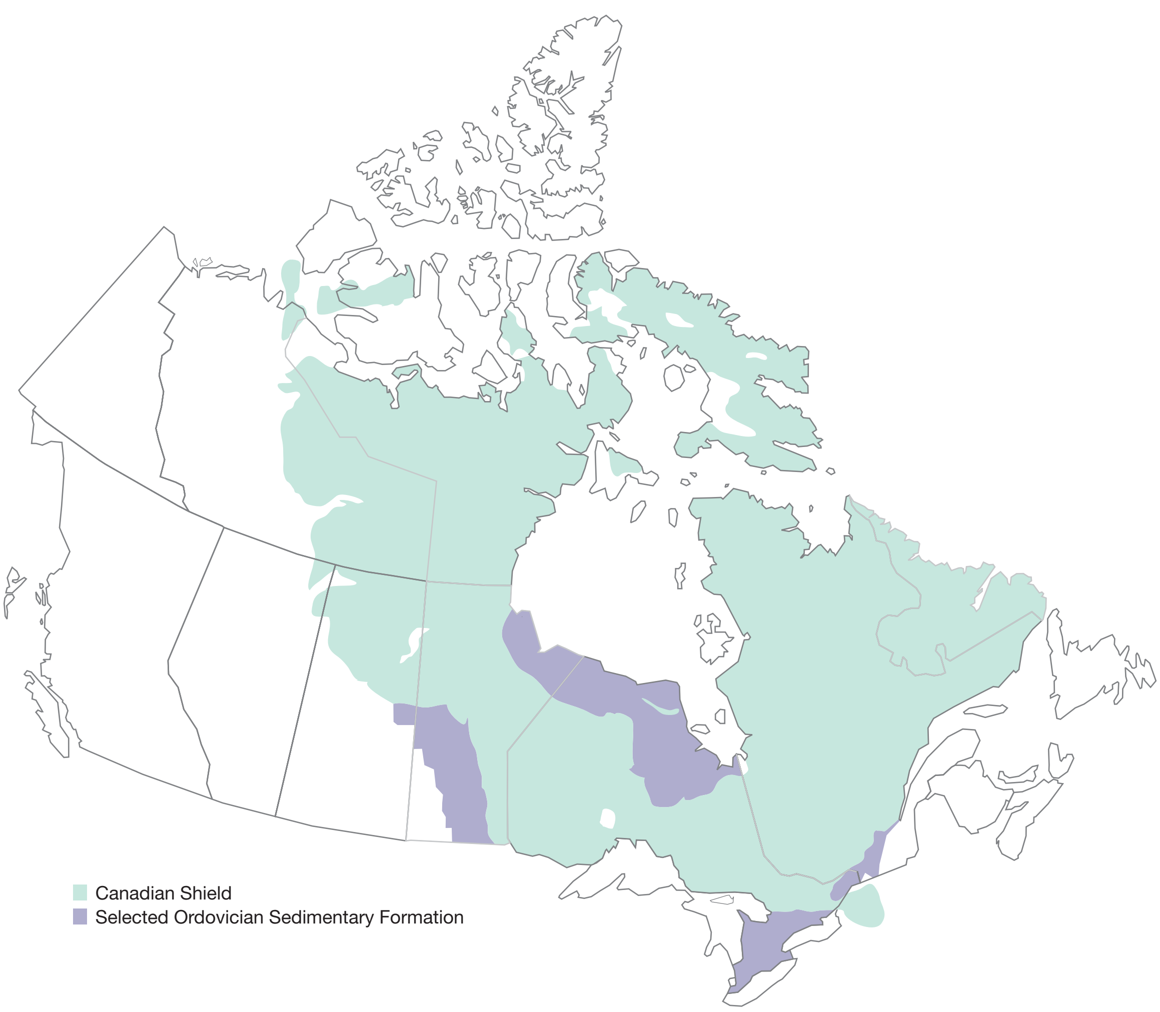
Notes: **UF** Used Nuclear Fuel, **R&D** Research and Development, **URL** Underground Research Laboratory at the central site.

Geotechnical and Other Siting Factors

Geotechnical investigations in Canada and elsewhere have confirmed that there are several types of geological formations that possess the features for long-term isolation. The scientific and technical siting factors include:

- Location in suitable rock such as the crystalline rock of the Canadian Shield or in the Ordovician sedimentary rock basins;
- Absence of known potential economic resources at depth;
- Sufficient surface area for receipt facilities and associated infrastructure.
- Seismically stable region with low known or projected frequency of high magnitude earthquakes;
- Low frequency of major groundwater conducting fracture zones, features or faults at repository depth;
- Geotechnically suitable host rock formation near surface for the shallow rock cavern vaults;
- Geotechnically suitable host rock formation at least 200 metres below surface with a preference for a suitable host rock formation between 500 and 1,000 metres below surface for the underground research laboratory and the deep geologic repository;

Figure A3-3 Example Regions of Potentially Suitable Rock Formations for a Central Facility



- Geochemically suitable (e.g., reducing) conditions in groundwater at repository depth;
- Evidence of rock mass homogeneity and stability at repository depth;
- Low hydraulic gradient and low permeability; and
- Diffusion controlled transport of dissolved minerals at repository depth.

Other environmental and social factors will also impact the siting process such as:

- Minimize distances for transporting used fuel and construction resources to the central facility;
- Avoidance of national and provincial parks, environmentally sensitive and protected areas, agricultural land, wetlands, permafrost; and
- Availability of road, rail or water transport options for used nuclear fuel.

The siting process will outline a complete set of siting principles and other factors in site selection.

Interim Storage at Reactor Sites

During the siting process, used fuel will continue to be safely stored on an interim basis at each of the reactor sites in Canada, in storage facilities licenced by the Canadian Nuclear Safety Commission. When used fuel is removed it is initially stored under several metres of water in used fuel bays adjacent to the reactors where it cools down for a period of seven to ten years. The fuel bundles are then transferred to dry storage facilities constructed at the reactor sites where they are encased in steel and concrete containers designed to absorb radiation and contain the material from the environment.

The design life of these dry storage facilities is typically about 50 years, although their life expectancy is expected to be 100 years or longer.

An example of wet and dry interim storage facilities is illustrated in Figures A3-4, A3-5 and A3-6.

Figure A3-4 Example of Used Fuel Storage in Fuel Bays at Reactor Site

Figure A3-5 & A3-6 Example of Used Fuel Storage in Dry Storage at Reactor Sites – Surface Storage Building and Dry Storage Containers

Continued Research and Technology Development

The siting period will also continue the necessary research and development of the technology for used fuel storage, transportation and isolation. For example, containers and handling systems for extended storage of used nuclear fuel in shallow underground rock caverns may need a design update (CTECH 2003b). Transportation systems for used fuel will need further development, testing and demonstration (Cogema 2003). And the mode of transportation: road, rail or water, may need further optimization to meet the needs of potential host communities for the central facility.

Research and development activities for a deep geologic repository will be required to identify, characterize, engineer, analyze, study, demonstrate and select the appropriate isolation technology and final site during the siting phase. This research and development will address development of site screening criteria and the site selection process, technical and social site characterization, biosphere and geosphere evaluation, computer model development, repository engineering and safety assessment activities conducted to support the feasibility studies in potential host communities, and the selection of a final engineering design and preferred site to support the safety and environmental impact assessment documents and related licensing activities. It would also include development of used fuel monitoring activities at repository depth, demonstration of used fuel container emplacement and retrieval technology at international underground research laboratories, vault sealing system development, security development work and further development of transportation technology, logistics and implementation schedule.

Initially, the research and development would take place at surface laboratories and at international underground research laboratories at generic sites such as the Äspö Hard Rock Laboratory in Sweden (SKB 2003). (Canadian organizations are currently participating in international research projects at Äspö). Later, the research and development would take place at the underground research laboratory at the preferred site in Canada.

The research and development program follows the step-wise implementation of the adaptive phased management approach with specific information designed to support the decision-making process. Examples of key technical decisions for long-term isolation of used fuel which would be supported by the research and development program include:

- Identification of potentially suitable geomedia at candidate sites for a deep geologic repository (e.g., crystalline rock, sedimentary rock);
- Identification of the site selection process and site screening criteria;
- Selection of candidate sites for a deep geologic repository from preliminary feasibility studies;
- Selection of the preferred host rock and depth for a shallow underground storage facility;
- Selection of the preferred host rock and depth for the deep geologic repository;
- Selection of the preferred site for the underground research laboratory and the deep geologic repository;
- Selection of long-term isolation design alternative (e.g., in-floor, in-room or long horizontal borehole emplacement of used fuel containers);
- Selection of the optimal transportation technology, route and logistics (timing);
- Identification of the repository monitoring system during used fuel container emplacement operations;
- Identification of the nuclear materials safeguards systems for used fuel transportation, storage and placement in a deep geologic repository;
- Identification of the repository monitoring system after used fuel container emplacement operations;
- Identification of design improvements for a deep geologic repository;

- Identification of the time period for extended monitoring of the deep geologic repository (after container emplacement operations are complete) and any impacts on the integrity of the used fuel containers within the emplacement rooms; and

- Support for a decision to decommission and close the facility.

It is expected that the Canadian research and development program would continue its international collaboration and joint R&D program activities with other waste management organizations such as Posiva, SKB and Nagra (Gierszewski et al. 2004) and seek opportunities to collaborate with other waste management organizations, as appropriate.

Construction of Shallow Rock Caverns for Extended Storage

Following the 20-year siting process and obtaining licences to build the central used fuel management facility, we will provide the option for secure underground storage of used fuel in shallow rock caverns constructed at a nominal depth of about 50 metres below surface. There will also be construction of surface buildings and associated facilities to receive used fuel and to provide repackaging of used fuel for underground storage, as required. Repackaging will depend in part on the eventual mode of used fuel transport from reactor sites: road, rail or water.

As indicated in Figure A3-1, the decision to construct the shallow rock caverns is assumed to occur in Year 20. This decision is also related to a decision to transport used fuel from the reactor sites to the central facility at about the same time. The need for centralized used fuel storage will depend on a number of social, technical and financial drivers which are not known at this point in time. The Adaptive Phased Management approach provides for this choice and the flexibility to proceed with extended storage at a central facility with used fuel transportation, or continued storage at reactor sites and delayed used fuel transportation until the deep geologic repository is available.

For design and cost estimating purposes, the NWMO has conservatively assumed that a central extended storage facility will be required and that it will take about 10 years to construct the shallow rock caverns and surface support facilities.

Construction of the Underground Research Laboratory

The underground research laboratory is planned to be constructed at a nominal depth between 500 to 1,000 metres below ground at the central facility. This is the depth where we expect the used fuel would eventually be emplaced for long-term containment, isolation and monitoring.

Since the 1980s, Canada and other countries have conducted many years of research into deep rock repositories for used nuclear fuel and high-level radioactive wastes. This underground laboratory would continue the site-specific research to improve our understanding and confirm the suitability of the site, and demonstrate the safety and feasibility of all aspects of the long-term isolation technology. Canada will also benefit from ongoing studies and demonstrations at international underground research laboratories. Following the licensing process, we anticipate that it will take about ten years to construct the shallow underground caverns and the underground research laboratory.

The next phase of development will build on the progress from the first phase, and will bring Canada's used nuclear fuel to a central site.

2.4 Phase 2: Central Storage and Technology Demonstration

Rock Cavern Storage and Used Fuel Transportation

Used fuel transportation will be required to move used bundles from reactor storage sites to a central facility for extended storage in the shallow rock caverns. The mode of transport will depend on the site chosen for the central facility. We anticipate it would take about 30 years to move the estimated 3.7 million used fuel bundles from Canada's seven nuclear reactor sites to the central site (Cogema 2003). This estimated used fuel inventory is based on the assumption that the current fleet of commercial nuclear power reactors in Canada have an average life of 40 years.

An example of a shallow rock cavern storage facility is illustrated in Figures A3-7 and A3-8 (CTECH 2003b).

Figure A3-7 **Used Fuel Storage in Shallow Rock Caverns at Central Facility – Ramp Access**

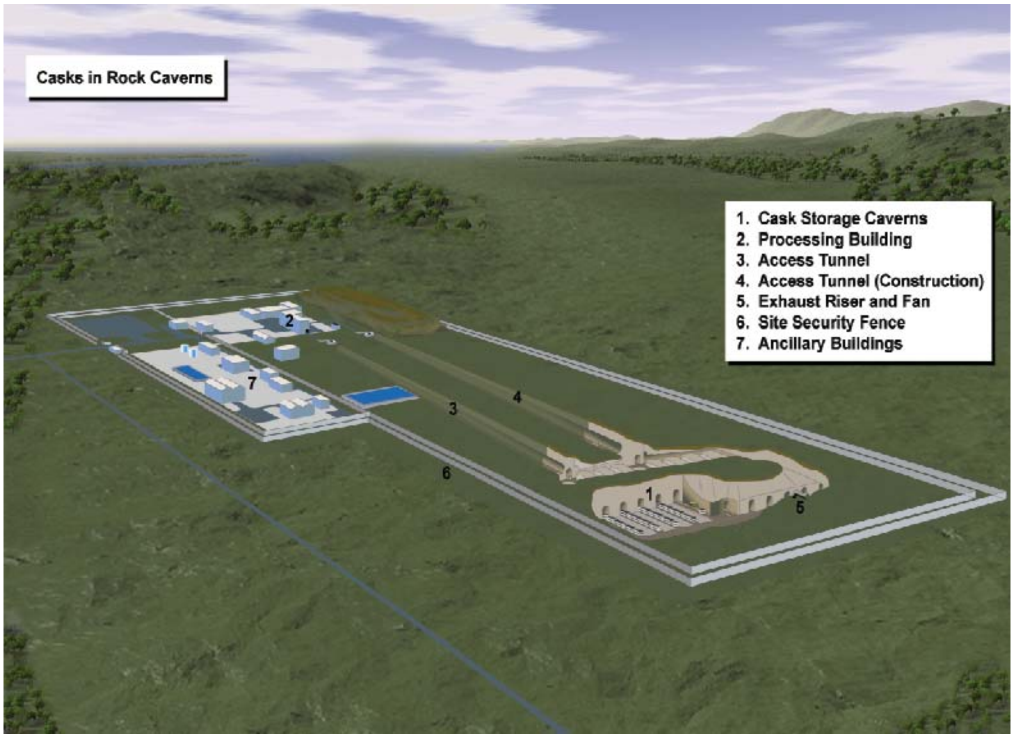
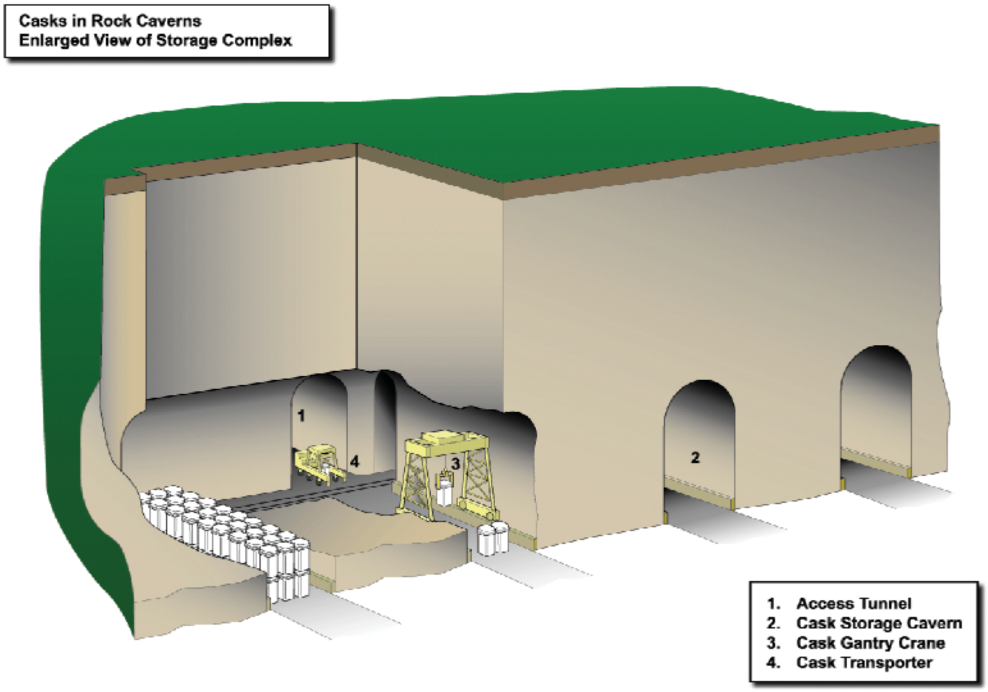


Figure A3-8 **Used Fuel Storage in Shallow Rock Caverns – Underground View**



Demonstration of Containment and Isolation Technology

The concept of containing and isolating used fuel in a deep geologic repository has gained widespread scientific credibility as the preferred long-term approach for dealing with wastes that remain hazardous for hundreds of thousands of years or longer. However, technical uncertainties remain, and further demonstration of the long-term isolation technology is required to build confidence in the safety and long-term reliability of the proposed system. We conservatively estimate that it will take up to 30 years of research and demonstration at the underground research laboratory to confirm the suitability of the site and to gain sufficient confidence in understand the long-term issues and prove the safety of isolating used fuel in a deep geologic repository. While doing our research and demonstrating the technology in-situ, we will continue to learn from the experiences in other countries with similar waste management programs. Our research will involve studies of the behaviour of the rock mass and groundwater flow at depth, and potential flow paths and long travel times for contaminants that may be released from used fuel containers and repository sealing systems. There will also be tests on engineered barrier materials and sealing systems and demonstration of techniques to retrieve used fuel containers should that be required in the future. There will also be extensive development and demonstration of monitoring equipment and methods.

Used Fuel – Resource or Waste?

Another issue that we expect will be addressed by the end of Phase 2 is whether or not used nuclear fuel is a potential resource for an advance nuclear fuel cycle or truly a waste. There are on-going international studies on how to reuse nuclear fuel or to treat it to reduce the volume of high-level waste material and potentially its radiotoxicity. These studies include research into reprocessing, partitioning (separation) and transmutation of the radionuclides in used fuel. These technologies are currently difficult to implement and very expensive, and they produce low and intermediate level radioactive wastes which will also require long-term management. There are also social and political concerns associated with reprocessing used nuclear fuel.

Based on current knowledge and understanding, reprocessing used nuclear fuel would add a significant increase to the cost of used fuel management and it would not negate the need for long-term containment and isolation of the residual high-level wastes in a deep repository (Jackson 2005). The NWMO will maintain a watching brief on this technology as it develops over the next few decades.

Construction of the Deep Geologic Repository

The final stage of Phase 2 would see the completion of design for long-term isolation of used fuel and the necessary licences for construction and operation of the deep geologic repository. We anticipate a period of about 20 years of investigations and demonstration of technology at the underground research laboratory, along with comments from the public and other interested stakeholders to prepare for the final phase of the approach.

After we have confirmed the suitability of the site and the isolation technology, we will completed the detailed engineering and safety assessments to apply for an Operating Licence for the deep geologic repository along with ancillary surface facilities such as the used fuel packaging plant and the sealing materials compaction plant (CTECH 2002). These facilities will be required to repackage the used fuel from storage containers into long-lived containers for placement in the deep repository.

We have allowed a period of 10 years to complete the work and construct the required facilities to receive used fuel in the deep repository. If we do not have sufficient information to proceed to the next step of concept implementation, then we have the option to continue further study and analyses to support the decision.

By the end of this phase, we expect to have sufficient knowledge and facilities to begin transfer of used fuel from centralized storage into long-term isolation in a deep geologic repository at the same site.

2.5 Phase 3: Long-term Containment, Isolation and Monitoring

Deep Geologic Repository

Based on current scientific knowledge, the best way to ensure long-term containment and isolation of used fuel is to put it in engineered systems underground in a deep geologic repository which will keep it isolated from humans and the environment for a very long time. This containment and isolation technology has been studied for many years in Canada and other nations.

An example of a deep geologic repository for used fuel is illustrated in Figure A3-9.

There is geotechnical evidence that suitable host rock formations are stable over hundreds of millions of years. In many respects a deep geologic repository would mimic conditions found in ore bodies such as Cigar Lake in northern Saskatchewan, where uranium is now mined to produce nuclear fuel. Buried deep underground, the radioactivity in used fuel would slowly decay to that found in the original uranium ore after hundreds of thousands of years.

A cutaway view of the Cigar Lake uranium ore natural analogue is illustrated in Figure A3-10. The basement rock is at a depth of about 400 metres below surface.

With the decision to construct a deep geologic repository, a new series of underground excavations would be constructed, likely at the depth of the underground research laboratory at 500 to 1,000 metres below surface. (See Figure A3-9). The used fuel bundles would be taken out of the shallow caverns and brought to the surface for repackaging into longer-lived used fuel containers for the deep repository.

Figure A3-9 Cutaway View of a Deep Geologic Repository at the Central Facility

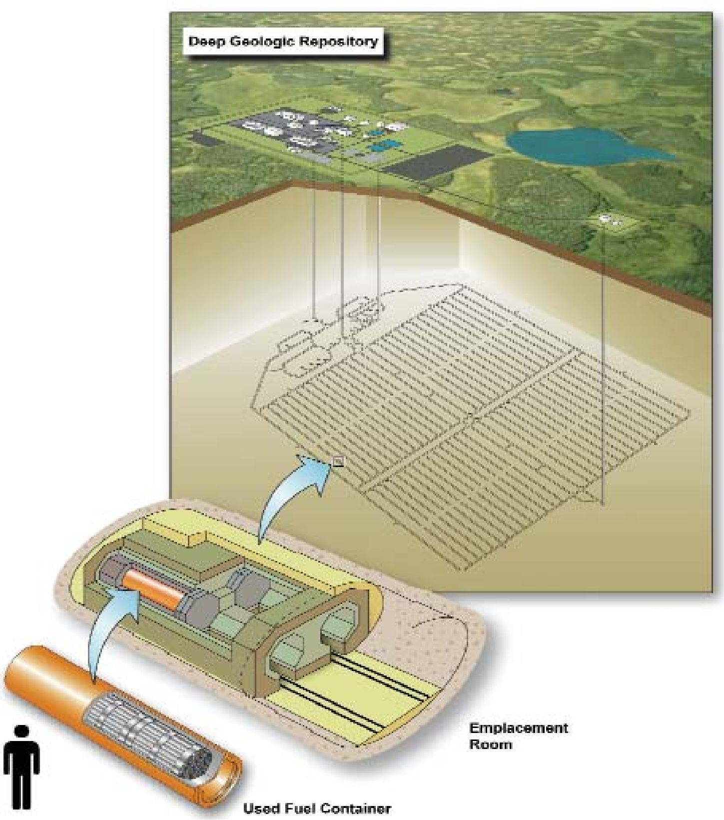
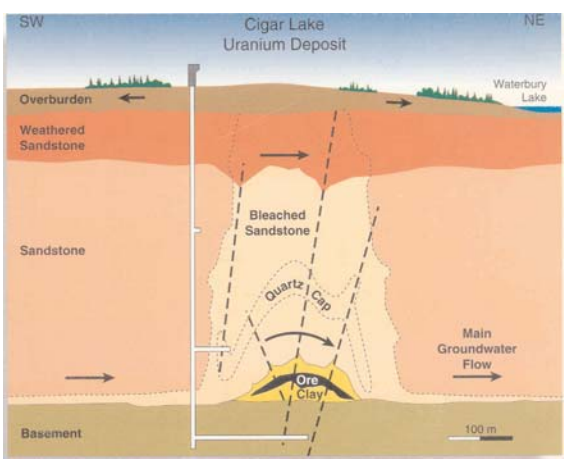


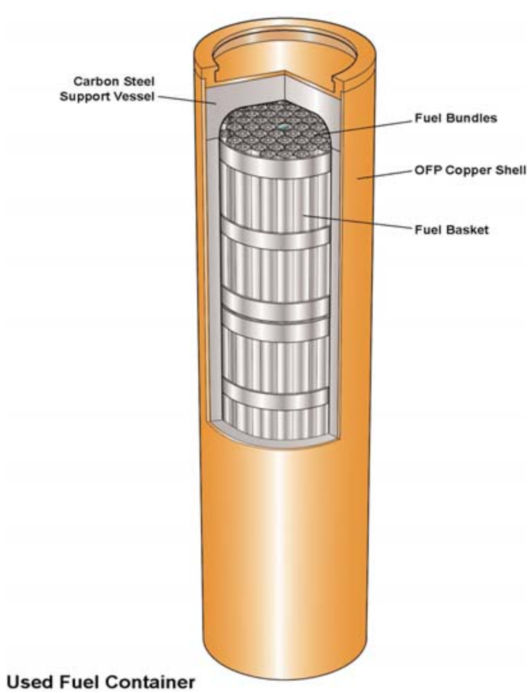
Figure A3-10 Cutaway View of the Cigar Lake Uranium Ore Natural Analogue



Used Fuel Containers and Sealing Materials

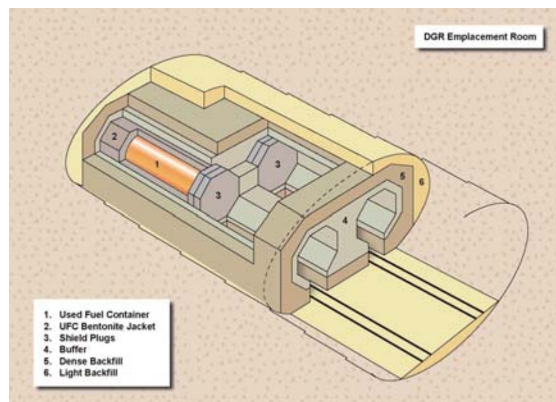
Based on the approaches studied in Canada, Sweden and Finland, we expect containers would consist of a steel structure covered by a corrosion-resistant copper barrier. They would have a design life of at least 100,000 years in a deep repository and they may last longer. The engineered barriers and the natural barrier provided by the host rock at the site will protect the used fuel containers from natural events such as climate change or future glaciations. The design of used fuel containers for long-term isolation in a deep geologic repository will undoubtedly evolve over the next few decades as research and technology demonstration activities progress in Canada and elsewhere. The current design for a used fuel container is illustrated in Figure A3-11. Other container designs are also feasible. The containers, each holding 324 used fuel bundles, would be transferred to the emplacement rooms in the deep repository and surrounded by further engineered barriers, such as clay-based sealing materials. Clay is also an excellent barrier to slow the movement of underground water and the movement of contaminants if a container is breached.

Figure A3-11 Example of Used Fuel Container and Inner Basket



An example of an emplacement room for used fuel containers is illustrated in Figure A3-12. In this particular configuration, used fuel containers are emplaced horizontally within the confines of the room. Other used fuel emplacement configurations include in-floor borehole and long horizontal tunnels (Gierszewski et al. 2004). Decisions on the emplacement method will depend on site-specific conditions at the central facility and on further engineering studies, analyses and demonstrations of technology.

Figure A3-12 Example Emplacement Room for Used Fuel Containers



Used Fuel Transfer from Shallow Storage to Deep Repository

Based on previous engineering studies, we estimate it will take about 30 years to transfer the storage containers holding all 3.7 million fuel bundles from the shallow rock caverns to the surface used fuel packaging plant and then down into the deep repository (CTECH 2002). As the used fuel containers are emplaced in the repository, the remaining void space in the rooms or boreholes holding the isolation containers would be backfilled with clay and concrete-based sealing materials, but the access tunnels and shafts to the surface could remain open for an extended period of time. This would allow in-situ monitoring of the stored fuel and retrieval of the used fuel container, if this was desired. After an additional 20 years, we are assuming that the shallow rock caverns which were used for extended storage would be closed. However, this shallow facility could be re-opened at a later time, if needed for used fuel container retrieval.

Decision to Close the Repository

We do not know how long a future society will want to maintain in-situ monitoring of used fuel via the open access tunnels and shafts. The decision to backfill and seal the access tunnels and shafts of the deep repository may take some time and we have allowed for this decision to take place after about 300-years. It may happen sooner. Final decommissioning and closure of the deep repository and surface facilities is expected to take about 25 years (CTECH 2002).

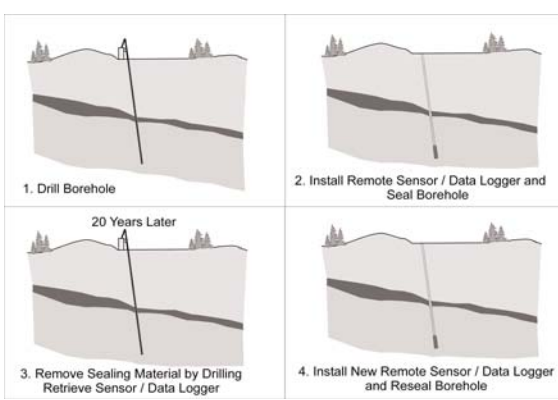
Internationally, there is some precedence for a proposed 300-year monitoring period. For example, the existing low and intermediate level waste facilities at Centre de l'Aube in France, the planned low-level waste facility at Dessel in Belgium and the proposed spent fuel facility at Yucca Mountain, Nevada all have provisions for 300 years of institutional control and monitoring.

Continued Postclosure Monitoring

Even after there has been a decision to close the deep facility, we are anticipating a need to provide a future society with the choice to continue monitoring the deep repository during the postclosure period. The concept for a passive system of postclosure monitoring of the deep repository has been developed and this monitoring is assumed to continue indefinitely.

An example of passive postclosure monitoring is illustrated in Figure A3-13.

Figure A3-13 System of Passive Postclosure Monitoring of a Deep Repository



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Cogema. 2003. Conceptual designs for transportation of used fuel to a centralized facility. Cogema Logistics Report 500276-B-005. (Available at www.nwmo.ca).

CTECH. 2002. Conceptual design for a deep geologic repository for used nuclear fuel. CTECH Report 1106/MD18085/REP/01. (Available at www.nwmo.ca).

CTECH. 2003a. Conceptual designs for reactor-site extended storage facility alternatives for used nuclear fuel. CTECH Report 1105/MD18084/REP/12. (Available at www.nwmo.ca).

CTECH. 2003b. Conceptual designs for four centralized extended storage facility alternatives for used nuclear fuel. CTECH Report 1105/MD18084/REP/08. (Available at www.nwmo.ca).

DPRA. 2005. Information and discussion sessions. The future management of Canada's used nuclear fuel. Regarding NWMO Discussion Document #2 Understanding the Choices. DPRA Summary Report, February 2005. (Available at www.nwmo.ca).

Gierszewski, P., S.B. Russell, A. D'Andrea, F. Garisto, M. Hobbs, M.R. Jensen, T.F. Kempe, P. Maak, G.R. Simmons and A. Vorauer. 2004. Deep geologic repository technology program – annual report 2003. Ontario Power Generation, Nuclear Waste Management Division Report 06819-REP 01200-10129-R00. (Available at www.nwmo.ca).

Golder/Gartner Lee. 2005. Supplemental report on assessment of benefits, risks and costs of a proposed adaptive phased management approach by illustrative economic region. Background Paper prepared by Golder Associates Limited and Gartner Lee Limited for the Nuclear Waste Management Organization. (Available at www.nwmo.ca).

Jackson, D.P. 2005. Implications of reprocessing, partitioning and transmutation on long-term management of used nuclear fuel in Canada. Background Paper 6-14 prepared by David P. Jackson, McMaster University for the Nuclear Waste Management Organization. (Available at www.nwmo.ca).

Mazurek, M. 2004. Long-term used nuclear fuel waste management – geoscientific review of the sedimentary sequence in southern Ontario. Background Paper 6-12 prepared by Rock-Water Interactions, Institute of Geological Sciences, University of Bern for the Nuclear Waste Management Organization. (Available at www.nwmo.ca).

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APPENDIX 4 / NWMO BACKGROUND RESEARCH

All NWMO Background Papers are available on-line at www.nwmo.ca/backgroundpapers.

Papers and reports completed and posted since the release of the NWMO's second Discussion Document are indicated below with an asterisk (*).

1. Guiding Concepts

1-1. Sustainable Development and Nuclear Waste. David Runnalls, IISD.

1-2. The Precautionary Approach to Risk Appraisal. Andy Stirling, University of Sussex.

1-3. Adaptive Management in the Canadian Nuclear Waste Program. Kai N. Lee, Williams College.

1-4. Nuclear Waste Management in Canada: The Security Dimension. Franklyn Griffiths, University of Toronto.

1-5. Risk and Uncertainty in Nuclear Waste Management. Kristen Shrader-Frechette, University of Notre Dame.

1-6. Thinking about Time. Stewart Brand, The Long Now Foundation.

1-7. Drawing on Aboriginal Wisdom. Joanne Barnaby, Joanne Barnaby Consulting.

1-8. Non Proliferation Aspects of Spent Fuel Storage and Disposition. Thomas Graham Jr. and James A. Glasgow, Morgan Lewis.

1-9. Is Safekeeping of Radioactive Waste Preferable to Disposal? The Importance of Semantics. Colin Allan and Paul Fehrenbach, Atomic Energy of Canada Ltd.

The NWMO asked experts in the field to comment on the Guiding Concepts papers, on the way in which the concepts have been defined, and implications for the long-term management of used nuclear fuel.

1-A Lloyd Axworthy: Comments on "Nuclear Waste Management in Canada: The Security Dimension" by Franklyn Griffiths.

1-B William Leiss: Comments on "Risk and Uncertainty in Nuclear Waste Management" by Kristen Shrader-Frechette.

1-C Edwin Lyman: Comments on "Nuclear Waste Management in Canada: The Security Dimension" by Franklyn Griffiths.

1-D Charles McCombie: Comments on "Adaptive Management in the Canadian Nuclear Waste Program" by Kai N. Lee.

1-E Robert Morrison: Comments on "Sustainable Development and Nuclear Waste" by David Runnalls.

1-F Ortwin Renn: Comments on "The Precautionary Approach to Risk Appraisal" by Andy Stirling.

2. Social and Ethical Dimensions

2-1. Ethics of High Level Nuclear Fuel Waste Disposal in Canada. Peter Timmerman, York University.

2-2. Social Issues Associated with the Atomic Energy of Canada Limited Nuclear Fuel Waste Management and Disposal Concept. Mark Stevenson, MAS Consulting.

2-3. Social Issues Associated with High Level Nuclear Waste Disposal. Maria Paez-Victor, Victor Research.

2-4. Long-Term Management of Nuclear Fuel Waste – Issues and Concerns Raised at Nuclear Facility Sites 1996 – 2003. Chris Haussmann and Peter Mueller, Haussmann Consulting.

2-5. Overview of European Initiatives: Towards a Framework to Incorporate Citizen Values and Social Considerations in Decision-Making. Kjell Andersson, Karita Research.

* 2-6. A Review of Waste Facility Siting Case Studies Applicable to Spent Nuclear Fuel Management Facilities and Associated Infrastructure. DPRA Inc.
This review of six waste facility siting studies attempts to identify and assess some of the experiences and lessons learned which might be applicable to the planning and siting of facilities for Canada's used nuclear fuel.

The NWMO asked selected individuals working in the field to provide additional comment on the issues raised in this series of papers.

2-A Ian J. Duncan: Social and Ethical Considerations "Canada's Used Nuclear Fuel – What to do with it!"

2-B Charles McCombie: Ethical Considerations "Status of Geological Repositories for Used Nuclear Fuel, Appendix B Ethical Issues".

2-C J.A.L. Robertson: "Nuclear Energy – An Ethical Choice".

3. Health and Safety

3-1. Status of Radiological Protection Technologies and Operational Procedures Related to High-level Radioactive Waste Management (HLRWM). Candesco Research Corporation.

3-2. Human Health Aspects of High-level Radioactive Waste. John Sutherland, Edutech Enterprises.

3-3. Status of Canadian and International Efforts to Reduce the Security Risk of Used Nuclear Fuel. SAIC.

3-4. Considerations in Developing a Safety Case for Spent Nuclear Fuel Management Facilities and Associated Infrastructure in Canada. K. Moshonas Cole, P.R. Reid and R.C.K. Rock, Candesco Research Corporation.

* 3-5. A Risk-Based Monitoring Framework for Used Fuel Management. Nava C. Garisto, SENES Consultants Ltd.
This paper provides an overview of a risk-based monitoring framework for used fuel management approaches. Various management methods are reviewed to estimate potential risks at each stage of their development. The results of the review are used to develop, at a conceptual level, a monitoring framework, which focuses on the main areas of potential risk.

4. Science and Environment

4-1. Status of Biosphere Research related to High-level Radioactive Waste Management. ECOMatters.

4-2. Characterizing the Geosphere in High-Level Radioactive Waste Management. Jonathan Sykes, University of Waterloo.

4-3. Natural and Anthropogenic Analogues – Insights for Management of Spent Fuel. Paul McKee and Don Lush, Stantec Consulting.

4-4. The Chemical Toxicity Potential of CANDU Spent Fuel. Don Hart and Don Lush, Stantec Consulting.

4-5. Review of the Possible Implications of Climate Change on the Long-Term Management of Spent Nuclear Fuel. Gordon A. McBean Ph.D., FRSC.

* 4-6. Review of the Implications of Microbiological Factors on the Long-term Management of Used Nuclear Fuel. D. Roy Cullimore, Ph.D. R.M., Droycon Bioconcepts Inc.
This paper outlines the need to recognize and include factors relating to subsurface biosphere in the design and establishment of any used nuclear fuel storage or disposal concepts that may be developed.

5. Economic Factors

5-1. An Examination of Economic Regions and the Nuclear Fuel Waste Act (*NFWA*). Richard Kuhn, University of Guelph and Brenda Murphy, Wilfred Laurier University.

5-2. Status of Financing Systems for High-level Radioactive Waste Management. GF Energy, LLC.

5-3. Considerations for the Economic Assessment of Approaches to the Long-Term Management of High-Level Nuclear Waste. Charles River Associates Canada Limited.

5-4. Economic and Financial Aspects of the Long-Term Management of High-Level Nuclear Waste: Issues and Approaches. Charles River Associates Canada Limited.

6. Technical Methods

6-1. Status of Reactor Site Storage Systems for Used Nuclear Fuel. SENES Consultants Ltd.

6-2. Status of Centralized Storage Systems for Used Nuclear Fuel. Mohan Rao and Dave Hardy, Hardy Stevenson and Associates.

6-3. Status of Geological Repositories for Used Nuclear Fuel. Charles McCombie, McCombie Consulting.

6-4. Status of Spent Fuel Reprocessing, Partitioning and Transmutation. David Jackson, David Jackson and Associates.

6-5. Range of Potential Management Systems for Used Nuclear Fuel. Phil Richardson and Marion Hill, Enviros Consulting Ltd.

6-6. Status of Transportation Systems for High-level Radioactive Waste Management. Wardrop Engineering Inc.

6-7. Status of Storage, Disposal and Transportation Containers for the Management of Used Nuclear Fuel. Kinectrics.

6-8. Review of the Fundamental Issues and Key Considerations Related to the Transportation of Spent Nuclear Fuel. Gavin J. Carter, Butterfield Carter and Associates, LLC.

6-9. Conceptual Designs for Used Nuclear Fuel Management. Joint Waste Owners, CTECH (a joint venture of CANATOM and AEA Technologies) and Cogema Logistics.

* 6-9 Financing the Management of Nuclear Fuel Waste The Joint Waste Owners (Ontario Power Generation Inc., Hydro-Québec, NB Power Nuclear and Atomic Energy of Canada Limited) have submitted to the NWMO, a proposal for financing the management of nuclear fuel waste, in response to the requirements laid out in the *NFWA*.

6-10. Review of Conceptual Engineering Designs for Used Nuclear Fuel Management in Canada. ADH Technologies Inc.

6-11. Validation of Cost Estimating Process for Long-Term Management of Used Nuclear Fuel. ADH Technologies Inc. and Charles River Associates Canada Ltd.

* 6-12. Long-term Used Nuclear Fuel Waste Management – Geoscientific Review of the Sedimentary Sequence in Southern Ontario. Martin Mazurek, Rock-Water Interaction, Institute of Geological Sciences, University of Bern, Switzerland.
This paper explores, from a geo-scientific perspective, the suitability of sedimentary rock for hosting a deep geological repository.

* 6-13. Conceptual Designs for Used Nuclear Fuel Management in Sedimentary Rock
These reports review potential changes to conceptual designs and cost estimates contained in Background Paper 6-9, which would be necessary should sedimentary rock be utilized for a Deep Geologic Repository or for below-ground Centralized Extended Storage.

* 6-14. Implications of Reprocessing, Partitioning and Transmutation on Long-term Management of Used Nuclear Fuel in Canada. David P. Jackson, McMaster University.
This paper provides an overview of economic and radiological implications of reprocessing, partitioning and transmutation in the context of the long-term management of used nuclear fuel in Canada.

7. Institutions and Governance

7-1. Status of the Legal and Administrative Arrangements for Waste Management in Canada. OCETA (Ontario Centre for Environmental Technology Advancement).

7-2. Status of the Legal and Administrative Arrangements for Low-level Radioactive Waste Management (LLRWM) in Canada. Paul Rennick, Rennick and Associates.

7-3. Status of the Legal and Administrative Arrangements for High-level Radioactive Waste Management (HLRWM). Mark Madras and Stacey Ferrara, Gowling Lafleur Henderson LLP.

7-4. Legal and Administrative Provisions for Radioactive Waste Management within the North American Free Trade Agreement (NAFTA). Aaron Cosbey.

7-5. Status of Canadian Expertise and Capabilities related to High-level Radioactive Waste Management. George Bereznai, UOIT (University of Ontario Institute of Technology).

7-6. Comparative Overview of Approaches to Management of Spent Nuclear Fuel and High Level Wastes in Different Countries. Charles McCombie and Bengt Tveiten.

7-7. Relevance of International Experiences in the Sound Management of Chemicals to the Long Term Management of Used Nuclear Fuel In Canada. John Buccini.

7-8. Review of the Canadian Environmental Assessment Act (CEAA) Process in Relation to Nuclear Waste Management. Robert S. Boulden, Boulden Environmental Consulting.

7-9. Review of the CNSC Licensing Process in Relation to Spent Fuel Management. J.F. Lafortune and F. Lemay, International Safety Research.

7-10. Review of the Legal and Administrative Aspects of the Non-Proliferation Treaty in Relation to Spent Nuclear Fuel Management. Mark Madras and Stacey Ferrara, Gowling Lafleur Henderson LLP.

7-11. Methodologies for Assessing Spent Nuclear Fuel Management Options. ETV Canada Inc., OCETA, Risk Wise Inc. and Science Concepts International.

* 7-12 Education and Training in Nuclear Waste Management
This paper identifies specific areas where training and capacity building in nuclear waste management may be required and surveys Canadian and international programs available to meet those needs.

8. Workshop Reports

8-1. Environmental Aspects of Nuclear Fuel Waste Management. Robert W. Slater, Coleman Bright and Associates, and Chris Hanlon, Patterson Associates.

8-2. Technical Aspects of Nuclear Fuel Waste Management. McMaster Institute for Energy Studies, McMaster University.

8-3. Drawing on Aboriginal Wisdom: A Report on the Traditional Knowledge Workshop. Joanne Barnaby, Joanne Barnaby Consulting.

8-4. Community Dialogue: Report of the Planning Workshop. Glenn Sigurdson CSE Consulting Inc. and Barry Stuart.

8-5. Looking Forward to Learn: Future Scenarios For Testing Different Approaches to Managing Used Nuclear Fuel in Canada, Global Business Network (GBN).

9. Assessments

9-1. Assessing the Options. The NWMO Assessment Team Report.
Upon release of the Assessment Team Report, the NWMO approached three individuals to learn their perspectives:
9-A Thomas Isaacs
9-B Tim McDaniels
9-C Barry Stuart

* 9-2. Assessment of Benefits, Risks and Costs of Management Approaches by Illustrative Economic Region. Golder Associates Ltd. and Gartner Lee Limited.
This report provides an assessment comparing the benefits, risks and costs of implementing, in illustrative regions of Canada the three methods of managing used nuclear fuel mandated for study by the Nuclear Fuel Waste Act, 2002.
Also see 3-5 A Risk-Based Monitoring Framework for Used Fuel Management. Nava C. Garisto, SENES Consultants Ltd.

10. Workshops and Roundtables

NWMO has completed a number of dialogue activities throughout the study. Reports from these dialogues are available at www.nwmo.ca/dialoguereports.

10-1. Report on Discussion with Senior Environmental and Sustainable Development Executives. Carole Burnham Consulting government Robert J. Readhead Limited.

10-2. Report on National Stakeholder and Regional Dialogues Regarding NWMO Discussion Document 1 "Asking the Right Questions." DRPA Canada.

10-3. Roundtable Dialogue with Youth at the International Youth Nuclear Congress – Summary Report. DRPA Canada.

10-4. Roundtable Dialogue with Durham Nuclear Health Committee – Summary Report. DRPA Canada.

* 10-5. Public Policy Forum: Implementing a Strategy for the Long-term Management of Used Nuclear Fuel. Public Policy Forum, December 2004. Results of a Roundtable with Senior Opinion Leaders conducted by Public Policy Forum in December 2004.

* 10-6. Dialogue: National Stakeholders and Regional Dialogue Sessions. Hardy Stevenson and Associates Final Report, February 2005. This report summarizes the results of four Dialogue Sessions with national and regional stakeholders. Participants commented on the Assessment Framework, and provided opinions about the strengths and limitations of the management approaches. They also provided advice on implementation considerations.

* 10-7. NWMO Workshop on Nature of the Hazard.
A workshop involving 16 individuals knowledgeable on various technical, environmental, health, social and ethical aspects of used nuclear fuel addressed the question "What is the nature of the hazard from used nuclear fuel." A facilitator's report and participants' statement summarize the results of that workshop.

* 10-8. Community Dialogue Workshop. Hardy Stevenson and Associates, February 2005
This report summarizes a February, 2005 workshop which reconvened participants from the 2003 Community Dialogue and representatives from the perspective of reactor site communities to provide comment on the Assessment Framework, and the strengths and limitations of the management approaches. They also provided advice on the NWMO's implementation strategy.

APPENDIX 5 / ENGAGEMENT ACTIVITIES

Throughout its study, the NWMO has sought to engage a broad range of individuals and communities of interest in an open dialogue. A number of mechanisms have been employed to solicit views and perspectives. Since the inception of the study, more than 5,000 people have participated in NWMO sponsored public attitude research and more than 5,000 have participated in other study activities, such as meetings, workshops, submissions and papers. The NWMO website has had more than 200,000 visits and 42,000 unique visitors, of which more than 8,000 have visited the website two or more times.

Aboriginal Dialogue

The purpose of the Aboriginal Dialogue is to build the foundation for a long-term positive relationship between the NWMO and the Aboriginal Peoples of Canada including Indian, Inuit and Métis.

The NWMO supports dialogue programs that are designed and implemented by the national Aboriginal organizations and by local or regional organizations where dialogues are desired and warranted. Aboriginal Dialogue reports are posted on the NWMO website as they are made available. www.nwmo.ca/aboriginaldialogues

National Associations

- The Assembly of First Nations (AFN) established a five-person National Working Group to guide its nuclear waste management dialogue process and to critique milestone NWMO documents. The AFN has developed an array of educational material for distribution to members. A Regional Council of Chiefs is reviewing environmental issues. A special program promotes youth involvement. The AFN has conducted the following meetings:
  - Working Group, Ottawa – July 14 – 15, 2004
  - Working Group, Ottawa – October 27, 2004
  - Regional Forum, Ontario South – November 18, 2004
  - Regional Forum, Ontario North – November 23, 2004
  - Regional Forum, Canada West – November 30, 2004
- The Congress of Aboriginal Peoples (CAP) initiated its dialogue program in 2004. A Steering Committee meeting was held on December 7, 2004 to discuss the national and regional programs and the initiation of the regional dialogues. The following dialogue sessions have since been held:
  - CAP – Western Office Calgary Dialogue Session – January 14, 2005
  - Native Council of Prince Edward Island Dialogue Session – February 5, 2005
  - New Brunswick Aboriginal Peoples Council Dialogue Session – February 26, 2005
  - Labrador Métis Nation Dialogue Session – February 27, 2005
  - Native Council of Nova Scotia Direct Mail/Key Informant Interviews – February – March 2005
  - Federation of Newfoundland Indians Dialogue with 9 Band Councils – March 2005
  - United Native Nations Dialogue Session – March 29, 2005
- Inuit Tapiriit Kanatami held two-day workshops in each of its four regional land claims components, Nunavut, Inuvialuit, Northern Québec and Labrador. A special session on nuclear fuel waste management took place during the National Inuit Conference on the Environment in February 2004.
- The Métis National Council conducted dialogues in each of its five regions: Ontario, Manitoba, Saskatchewan, Alberta, and British Columbia. A national coordinator links teams in each of the regions.
- The Pauktuutit Inuit Women's Association brought together women from across the Arctic to a workshop in Ottawa on November 4, 2004 to discuss the issue.

Regional/Local Organizations

- The **Ontario Métis Aboriginal Association** conducted dialogues in small communities throughout Ontario reaching out to over a thousand people and is continuing its efforts to convene dialogues in its other four regions including Manitoba, Saskatchewan, Alberta, and British Columbia. A national coordinator links teams in each of the regions.

- The **Sakitaawak Métis Society, Northwest Saskatchewan** hosted a community retreat bringing together representatives from 19 towns and villages, five First Nations, the uranium mining industry and the NWMO.

- Community elders from the **Eabametoong First Nation, Fort Hope, Ontario** led a four-part process aimed at exploring all of the issues related to the long-term management of used nuclear fuel in Canada, and in particular, implications for Aboriginal Peoples.

- The **East Coast First People's Alliance, New Brunswick** brought together non-status, off-reserve and unaffiliated Aboriginals in New Brunswick for a workshop.

- The **Western Indian Treaty Alliance**, representing non-status, off-reserve and unaffiliated Aboriginals in Alberta, Saskatchewan and Manitoba formed a Steering Committee and arranged regional meetings in Edmonton and Regina.

- The **Atlantic Policy Congress of First Nation Chiefs**, a regional affiliate in the Maritimes of the Assembly of First Nations conducted regional dialogues.

E-Dialogues

Royal Roads University, facilitated by Dr. Ann Dale, conducted three internet-based e-dialogues on behalf of the NWMO:

- On October 26, 2004 risk and uncertainty in the management of nuclear waste was explored by the following panelists: Norm Rubin of Energy Probe, William Leiss of the School of Policy Studies at Queen's University, Andrew Stirling of Science and Technology Policy Research at the University of Sussex, Environmental Studies at Williams College, and the David Shoesmith of Department of Chemistry at the University of Western Ontario.

- On November 29, 2004 approximately 75 young people were engaged in the conduct of four e-roundtables to apply a decision-making framework to the three options for used nuclear fuel that the NWMO is required to study. Participants drew from Parliamentary Interns, Action Canada Senior Policy Fellows, Top Forty Under Forty, members of the doctoral science cohort across North America, youth wings of the three major political parties, Royal Roads students, former graduates and Trudeau Scholars.

- On February 10, 2005, decision-making under conditions of risk and uncertainty was explored by the following panelists: Christopher Henderson of the Delphi Group, Norm Rubin of Energy Probe, Jim MacNeill formerly of the Brundtland Commission and of the World Bank's Independent Inspection Panel, and Andy Stirling from the University of Sussex.

From October 2004 to February 2005 the Royal Roads website which accommodated the NWMO e-dialogues recorded 3203 visits. See www.nwmo.ca/edialogues.

Information and Discussion Sessions

Between September and December 2004, 880 citizens participated in well-advertised public information and discussion sessions convened in every province and territory in Canada. The purpose was to inform Canadians about the NWMO study and to engage them in a dialogue about the preliminary descriptions of long-term nuclear waste management approaches and the framework being proposed to compare them.

A total of 120 meetings occurred in:

Whitehorse	Yellowknife	Iqaluit
Vancouver	Edmonton	Regina
Pinawa	Winnipeg	Kenora
Huntsville	Sudbury	Thunder Bay
Kingston	Timmins	London
Toronto	Ottawa	Pembroke
Pickering	Clarington	Owen Sound
Bécancour	Québec City	Sept-Îles
Rivière-du-Loup	Rouyn-Noranda	Edmundston
Montréal	Musquash	Fredericton
Halifax	Charlottetown	St. John's
Goose Bay		

Summary reports from each of these sessions and a comprehensive report summarizing all of the activities and discussions are available on the NWMO website: www.nwmo.ca/infoanddiscussion.

National Citizens Dialogue

The NWMO partnered with the Canadian Policy Research Networks (CPRN) to bring together 462 citizens for a dialogue about their underlying values and expectations. The goal was to understand how the public at large approaches the complexities involved in the long-term management of used nuclear fuel.

The Dialogue took place between January and March 2004, in 12 locations across the country:

Halifax	Moncton	Québec City
Montréal	Toronto	London
Thunder Bay	Sudbury	Ottawa
Saskatoon	Calgary	Vancouver

Participants were randomly selected by a polling firm to be representative of the Canadian population.

Using quantitative and qualitative data from the dialogue sessions, CPRN analyzed the results and reported on the core values Canadians would like to see drive decision-making. The full report is available on our website at: www.nwmo.ca/canadianvalues.

National and Regional Dialogues

In March and April 2004, the NWMO held national and regional dialogues in Ottawa, North Bay, Montréal, and Fredericton. These meetings brought together seventy-three people and organizations with a history of involvement in the subject of how Canada should manage its nuclear fuel wastes and others with an interest in similar public policy issues. Participants were asked to critically review the NWMO's first discussion document, *Asking the Right Questions?*

Dialogues consisted of an introductory half-day session, followed by an electronic dialogue, and several weeks later, a full-day facilitated discussion in which participants returned to address a range of topics in depth and to explore their views further.

The National and Regional Dialogues were re-convened in January and February 2005 to review the NWMO's second discussion document *Understanding the Choices* and to seek input on the preliminary assessment of the management options and the NWMO's implementation strategy.

Fifty-nine people participated in these re-convened dialogues held in Toronto, Mississauga, Fredericton and Montréal. The two-day sessions included an exercise designed to assist participants in their understanding of the assessment framework presented in *Understanding the Choices* and was followed by an in-depth discussion of the questions posed in the document.

Project findings for both the initial and follow-up national and regional dialogues are available on the NWMO website at: www.nwmo.ca/regionaldialogues.

Public Attitude Research

An important component of the NWMO outreach has been to track the views of Canadians through public attitude research including discussion groups and telephone surveys. Reports on these activities are posted on the NWMO website: www.nwmo.ca/publicattituderesearch.

In November and December 2002 an independent research company conducted 14 discussion sessions in Pickering, London, Thunder Bay, Saskatoon, Vancouver, St. John and Trois-Rivières to help identify a range of needs and expectations of Canadians regarding the NWMO study. The same issues were explored in a national telephone survey of 1,900 scientifically selected people representative of a cross-section of Canadians and 700 individuals living in nuclear site communities.

In December, 2003, six discussion sessions were held with 54 participants in North Bay, Kanata and Mississauga to gauge their reaction to the first NWMO discussion document, *Asking the Right Questions?* Similar questions were asked in a national telephone survey of 1900 Canadians from coast-to-coast and 700 citizens from nuclear site communities in spring, 2004.

Ten focus groups with 96 participants were convened in Pickering, Sault Ste. Marie, Windsor, St. John and Québec City in winter, 2004/05. These sessions were designed to provide insight into how people approach trade-offs and balances that will be required in developing a recommendation for the long-term management of used nuclear fuel.

Reactor Site Community Dialogues

The NWMO recognized early that communities which currently store used nuclear fuel have special experience, insights and perspectives which should be drawn upon to inform the NWMO study. Each of these communities was visited.

In October 2003 a Community Dialogues Planning Workshop was convened in Toronto to develop ways of enabling reactor site communities to participate meaningfully in the process. Twenty-one individuals participated, representing various perspectives including: environment, labour, industry, business, citizen, health and local government. They were drawn from communities in the vicinities of the seven nuclear storage sites in Canada: Point Lepreau in New Brunswick; Gentilly in Québec; Darlington, Pickering, Bruce and Chalk River in Ontario; and Whiteshell in Manitoba.

Community Dialogue Workshop

In February 2005 participants from the 2003 workshop were reconvened for a two-day session in Toronto to review the NWMO's second discussion document *Understanding the Choices* and to seek their input on the preliminary assessment of the management options and the NWMO's implementation strategy.

The two-day dialogue included an exercise designed to assist participants in their understanding of the assessment framework presented in the NWMO's second discussion document and was followed by an in-depth discussion of the questions posed in *Understanding the Choices*.

Thirteen participants attended these sessions.

Reports of the Community Dialogue Workshops are available on the NWMO website: www.nwmo.ca/workshopreports.

Other Dialogues with Reactor Site Communities

Throughout its study the NWMO has conducted ongoing dialogue and study updates through meetings with individual Mayors, and through the Canadian Association of Nuclear Host Communities.

Citizens from reactor site communities participated in the Information and Discussion sessions held across Canada from October to December 2004.

Also, at their request, information has been presented to citizen groups, advisory committees, local health committees, municipal councils and planning committees in nuclear communities. Among them:

Ajax City Council
Durham Nuclear Health Committee
Ajax Rotary Club
Renfrew Concerned Citizens
Pickering Community Advisory Committee
Deep River Area Mayors
Deep River CNS
South Bruce Impact Advisory Committee
Darlington Site Planning Committee

Workshops and Roundtables

Workshops and meetings have been convened to explore specific topics and key issues. These sessions include:

- Sept. 2003, Wanuskewin Heritage Park; Drawing on Aboriginal Wisdom, A Report on the Traditional Knowledge Workshop
- Sept. 2003, Ottawa; Environmental Aspects of Nuclear Fuel Waste Management
- Sept. 2003, Hamilton; Technical Aspects of Nuclear Fuel Waste Management
- Oct. 2003, Toronto; Social Issues Roundtable Discussion
- June – Oct. 2003, Toronto; Looking Forward to Learn: Future Scenarios for Testing Different Approaches to Managing Used Nuclear Fuel in Canada (four workshops)

- Sept. 2003 – March 2005, Toronto; Roundtable on Ethics
- Jan. 2004, Toronto and Calgary; Corporate Environmental and Sustainable Development Executives
- April 2004, Pickering; Roundtable Dialogue with Durham Nuclear Health Committee
- May 2004, Toronto; Roundtable Dialogue with Youth at the International Youth Nuclear Congress
- Dec. 2004, Toronto; Dispute Resolution Workshop
- Feb. 2005, Toronto; Nature of the Hazard Workshop

Government

The NWMO conducts workshops and provides briefings and written updates for elected representatives and members of the public service. The NWMO has presented to the federal Standing Committee on Environment and Sustainable Development, and to a number of federal and provincial departments and agencies.

International

The NWMO stays abreast of international standards and best practices for the long-term management of used nuclear fuel through attendance at international conferences, meetings with national and international organizations and international site visits.

Website

The NWMO website was visited 206,500 times between February 2003 and April 2005. In that period, the website was visited by 42,729 unique visitors, 8,272 of which visited the website two or more times, based on Web Trends reporting. In that same period, more than 140 submissions were made to the website.

Other

Early in its work the NWMO initiated approximately 250 Conversations About Expectations with individuals and organizations to learn what they expected from the NWMO study and how they wanted to see it conducted.

The NWMO initiates and responds to requests for information sessions and presentations. Among these:

Nuclear Waste Watch
Timmins Citizen's Group
International Youth Nuclear Congress
University of Toronto
Federation of Northern Ontario Municipalities
Public Policy Forum
Canadian Nuclear Association
Canadian Nuclear Society
Various Community Events
GLOBE 2004
Lakehead University
Ontario Bar Association
Canadian Nuclear Workers Council
Atomic Energy of Canada Ltd.
Canadian Institute
Canadian Gas Association
GE Canada
NACE (Corrosion Society)
North Saskatoon Business Association
Council of Regional Councils
Public Sector Executives Network
Canadian Nuclear Safety Commission
Canadian Environmental Assessment Agency
United Church of Canada
Atomic Energy Canada Limited Research and Development Advisory Panel

APPENDIX 6 / ETHICAL AND SOCIAL FRAMEWORK

NWMO's Roundtable on Ethics has suggested an Ethical and Sound Framework to guide the work of the NWMO. This framework is repeated in it's entirety below.

March 4, 2005

Nuclear Waste Management Organization Roundtable on Ethics

The Roundtable on Ethics has developed the following Ethical and Social Framework within which to consider the management of spent nuclear fuel, as was recommended by the Environmental Assessment Panel in its report to the federal cabinet. The Roundtable recommends that the NWMO adopt this framework, publish it in NWMO documents and on the NWMO website, and conduct its activities in the light of it. The Roundtable may refine the framework further as the work of the NWMO progresses.

Andrew Brook
Wesley Cragg
Georges Erasmus
David MacDonald
Arthur Schafer
Margaret Somerville

Ethical and Social Framework

Recognizing that everyone contributing to the NWMO's work seeks to use procedures and make recommendations that are ethically sound, the NWMO commits itself to embed ethics in all its activities. The aim is to ensure that its work, its ultimate recommendations, and their implementation reflect the highest ethical standards. To assist the NWMO in achieving its ethical goals, the Roundtable on Ethics has constructed a framework of questions designed to guide its deliberations and its ultimate recommendations. These questions aim to identify basic values, principles, and issues.

The ethical principles incorporated in the framework include: respect for life in all its forms, including minimization of harm to human beings and other sentient creatures; respect for future generations of human beings, other species, and the biosphere as a whole; respect for peoples and cultures; justice (across groups, regions, and generations); fairness (to everyone affected and particularly to minorities and marginalized groups); and sensitivity to the differences of values and interpretation that different individuals and groups bring to the dialogue. These principles apply both to the consultative and decision-making procedures used by the NWMO and to the recommendations that it will make.

Given the large stockpile of highly radioactive spent fuel that already exists or will be created in the lifespan of existing reactors and that will be hazardous for a very long period, likely hundreds of thousands of years or longer, some solution to managing this material as safely and effectively as possible must be found.

The goal is to find and implement an ethically sound management approach. However, if no ethically sound management approach exists, adopting the ethically least-bad option available to deal with existing and committed spent fuel would be justified.

By contrast, the creation of new spent fuel (that is, beyond what already exists or will be created in the lifespan of existing reactors) and, thereby, the issue of its disposal, must be judged by the standard of full ethical soundness. If the best current proposal does not meet this standard, then it would not be justified to create new material. To justify creating new spent fuel from an ethical point of view, there must be a management solution that is ethically sound, not just least bad. (The other ethical issues associated with nuclear power generation would have to be resolved, too, problems such as the effects of uranium mining and mine tailings, vulnerability of spent fuel to terrorist attacks, safety of the reactors, danger of diversion for nuclear weapons, and whether increased nuclear power generation can be justified, given the available options.) Moreover, even a least-bad option acceptable for the existing problem might cease to be acceptable if there were changes in the nature of the spent fuel, such as adding spent enriched fuel.

In short, a solution that is ethically acceptable for dealing with existing spent fuel is not necessarily a solution that would be ethically acceptable for dealing with new or changed materials. Thus, a question that urgently needs to be addressed is whether the NWMO is dealing simply with existing materials and those that will be created in the lifespan of existing reactors or also with substantial additional spent fuel? And this is no less than the question: What will the future of nuclear power in Canada be?

Ethical Questions Relevant to the NWMO's Procedures

Some of the questions that arise concerning procedures are:

Who should participate in the decision-making process?

What principles should guide consultations, deliberations, and the making of decisions?

When facts are in dispute or unavoidably uncertain, how should the NWMO proceed?

These general questions give rise to more specific ones. The list of questions that follow is not meant to be exhaustive. For each question, the principle(s) involved is/are in boldface type.

Q1. Is the NWMO conducting its activities in a way appropriate to making public policy in a **free, pluralistic, and democratic society**? In particular, are its activities **open, inclusive, and fair** to all parties, giving everyone with an interest in the matter an opportunity to have their views heard and taken into account by the NWMO? Are groups most likely to be affected by each spent fuel management option, including the transportation required by some of the options, being given full opportunity to have their views heard and taken into account by the NWMO? Is the NWMO giving special attention to Aboriginal communities, as is mandated by the governing legislation?

Q2. Are those making decisions and forming recommendations for the NWMO **impartial**, their deliberations not influenced by conflict of interest, personal gain, or bias?

Q3. Are groups wishing to make their views known to the NWMO being provided with the **forms of assistance** they require to present their case effectively?

Q4. Is the NWMO committed to basing its deliberations and decisions on the **best knowledge**, in particular, the best natural science, the best social science, the best Aboriginal knowledge, and the best ethics – relevant to the management of nuclear materials, and to doing assessments and formulating recommendations in this light? Equally, have limits to the current state of knowledge, in particular **gaps** and areas of **uncertainty** in current knowledge, been publicly identified and the interpretation of their importance publicly discussed and justified?

Q5. Does the NWMO provide a **justification** for its decisions and recommendations? In particular, when a balance is struck among a number of competing considerations, is a justification given for the balance selected?

Q6. Is the NWMO conducting itself in accord with the **precautionary approach**, which first seeks to **avoid harm and risk of harm** and then, if harm or risk of harm is unavoidable, places the burden of proving that the harm or risk is ethically justified on those making the decision to impose it?

Q7. In accordance with the doctrine of **informed consent**, are those who could be exposed to harm or risk of harm (or other losses or limitations) being **fully consulted** and are they willing to accept what is proposed for them?

Ethical Questions Relevant to the NWMO's Recommendations

As before, key ethical principles are in boldface type.

Q8. Do the NWMO's recommendations reflect **respect for life**, whatever form it takes, wherever it occurs, and whenever it exists (now and into the foreseeable future)? In particular, are the NWMO's recommended solutions likely to protect human beings, including future generations, other life forms, and the biosphere as a whole into the indefinite future?

Q9. Is a reasonable attempt being made to determine, in so far as it is possible to do so, the **costs, harms, risks, and benefits** of the options under consideration, including not just financial costs but also physical, biological, social, cultural, and ethical costs (harm to our values)?

Special ethical issues arise with respect to risk assessment in the nuclear industry. For example, might some scenarios be so horrendous that even a slight risk of their occurrence would be morally unacceptable or unacceptable by Canadians?

Q10. If implemented, would the NWMO's recommendations be **fair**?

This question breaks down into a number of sub-questions:

Are the beneficiaries of nuclear power (past, present and perhaps future) bearing the costs and risks of managing spent fuel and other nuclear materials in need of treatment? Do the recommended provisions avoid imposing burdens on people who did not benefit from the activities that created the spent fuel?

Are costs, risks, and benefits to the various regions affected by the use, possible transport, and disposal of the materials being distributed fairly?

Are the interests of future generations and non-human life forms being respected?

Are the rights of individuals and minorities being respected, especially vulnerable individuals and minorities?

Q11. Do the recommended provisions protect the **liberty** of future generations to pursue their lives as they choose, not constrained by unresolved problems caused by our nuclear activities? Do the recommended provisions maximize the range of choice open to future generations?

Important Specific Issues

In connection with Q8 to Q11, at least four specific issues merit special consideration.

1. Monitoring, remediation, and, if needed, reversal. Are sound provisions being made to check on whether management provisions are working as designed? If problems appear, are provisions being made to gain the access needed to fix them? Is the issue of reversal if something goes seriously wrong being taken into account?

2. Risk reduction vs. access. What is the appropriate balance between reducing risk to the greatest extent possible and retaining access to the materials, for remediation, for example, or to recover valuable materials from them?

3. Permanent or interim? Is it ethically acceptable to seek a permanent solution now or would it be preferable to recommend an interim solution in the hope that future technological improvements might significantly lower the risks or diminish the seriousness of the possible harms?

4. Lessons to be learned. What lessons can we learn for the future of the nuclear power generation industry from the problem of management of spent fuel and the NWMO's efforts to resolve it?

In closing, we will repeat a point made earlier. Because we must manage already-existing and already-committed spent fuel in some way, here the least-bad option is an ethically acceptable option. By contrast, new spent fuel – whether generated by new reactors, by replacing existing reactors as they reach the end of their serviceable life, or by importing material from other countries – is ethically another matter altogether. For the creation of new spent fuel to be ethically justified, it would have to be shown that there exists a management option that is ethically sound, not just least bad. (Other ethical issues to do with nuclear power generation such as the ones mentioned above would have to be resolved, too.)

APPENDIX 7 / STATUS OF USED NUCLEAR FUEL IN CANADA

In Canada, producers and owners of used nuclear fuel are responsible for its interim management. After seven to ten years in water-filled storage bays, used fuel bundles are transferred to dry storage facilities at the reactor sites.

The uranium mass of a CANDU fuel bundle is approximately 19.2 kilograms. As of December 31, 2004, Canada had 35,971 tonnes of uranium in its used nuclear fuel.

Electricity Generating Stations

Bruce Power operates six of eight reactors at the Bruce Nuclear Generating Stations (NGS) in Kincardine, Ontario. The company reported on March 21, 2005 that it had reached a tentative agreement with a negotiator appointed by the Province of Ontario for the potential restart of two additional units, one of which was shut down in October 1995, and the other in October 1997. Current operating licences for both Bruce A and Bruce B expire on March 31, 2009.

Ontario Power Generation Inc. (OPG) operates the Pickering Nuclear Generating Stations in Pickering, Ontario. All four reactors at the Pickering B plant are in service. Estimated operating lives for these reactors range from 2013 to 2016. The current Pickering B operating licence expires on June 30, 2008.

One of four units at Pickering A was returned to service in September 2003. It had been shut down along with the other three Pickering A units in 1997. A second of the shut down units is being returned to service. Pressure tubes at Pickering A were replaced between 1984 and 1993. As a result, OPG extended the operating life estimate for the plant to 2023. The current operating licence for Pickering A expires on June 30, 2005.

OPG also operates four reactors at the Darlington NGS in Clarington, Ontario. The estimated operating life of these units ranges from 2018 to 2019. The current operating licence for Darlington expires on February 29, 2008.

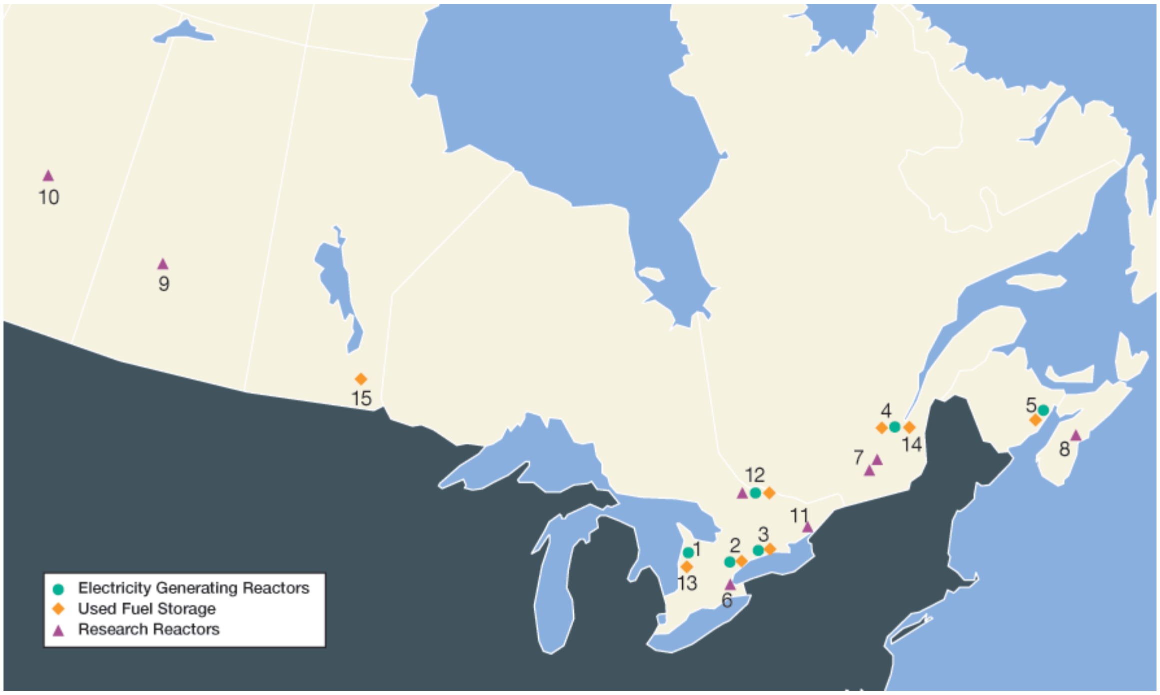
Hydro-Québec operates one reactor at the Gentilly-2 NGS in Bécancour, Québec. The power plant is designed to operate until 2013. No decision has been taken on a company proposal to refurbish the plant, extending its life to 2035.

Table A7-1 Storage of Used Nuclear Fuel as of December 31, 2004

Storage Location	Licensee	Bundles in Reactor(s)	Bundles in Wet Storage	Bundles in Dry Storage	Total Fuel Bundles
Bruce A	Bruce Power[1]	12,480	361,271		373,751
Bruce B	Bruce Power[1]	24,575	369,344	29,184	423,103
Pickering	OPG	36,744	382,332	135,927	555,003
Darlington	OPG	24,960	256,068		281,028
Douglas Point	AECL[2]			22,256	22,256
Chalk River	AECL[3]			4,853	4,853
Gentilly 1	AECL[4]			3,213	3,213
Gentilly 2	HQ	4,560	33,814	60,000	98,374
Pt. Lepreau	NBP	4,560	39,482	63,180	111,562
Whiteshell	AECL[5]			360	360
TOTAL		107,879	1,442,311	318,973	1,873,503

1 OPG manages used fuel produced by Bruce Power which leases the Bruce reactors from OPG.
2 The Douglas Point Nuclear Generating Station in Kincardine, Ontario was shut down in 1986.
3 Chalk River Laboratories (CRL), near Deep River, Ontario is a nuclear research facility with test reactors, fuel inspection and other facilities. Most of the used fuel bundles in the CRL dry storage area are from the Nuclear Power Demonstration (NPD) reactor which was de-fueled in 1987. A quantity of non-standard fuel waste is also stored at the CRL.
4 Gentilly 1, at Becancour, Québec was shut down in 1977.
5 The dry storage facility at Whiteshell, Manitoba houses research reactor fuel rods and some used fuel bundles from the shutdown Douglas Point reactor.

Figure A7-1 **Nuclear Reactor Sites in Canada**



The operating licence for Gentilly-2 expires on December 31, 2006.

NB Power Nuclear operates one reactor at the Point Lepreau NGS in Point Lepreau, New Brunswick. Its current operating licence expires on December 31, 2005. No decision has been taken on an NB Power proposal to refurbish the power plant beginning in 2008 and extending its service life for 25 to 30 years beyond the refurbishment completion date.

Research Reactors

Canada has a number of research and isotope-producing reactors. These include five SLOWPOKE reactors located at: École Polytechnique in Montréal, Dalhousie University in Halifax, Royal Military College in Kingston, the Saskatchewan Research Council in Saskatoon, and the University of Alberta in Edmonton. SLOWPOKE reactors, which use U-235 enriched fuel, can operate on one fuel charge for 20 to 40 years. The total mass of the fuel in a SLOWPOKE reactor core is one to five kilograms. Used fuel from some of these reactors has been shipped to the AECL site at Chalk River, Ontario.

AECL has operated research reactors to support nuclear R&D and/or produce medical isotopes since 1945. At Chalk River Laboratories (CRL), AECL operates the NRU, MAPLE 1 and MAPLE 2 production reactors, and a low-power ZED-2. The NRX reactor is shut down. Non-operating low-power reactors at CRL include PTR and ZEEP. AECL operated two reactors, WR-1 and SLOWPOKE Demonstrator (SDR) at its Whiteshell site in Manitoba. Both are shut down.

Used fuel from Canada's SLOWPOKE and AECL reactors is divided into about 70 different types, each with its own characteristics. AECL has long-term management strategies applicable to all used fuel arising from these research reactors.

McMaster University in Hamilton operates a pool-type reactor. Used fuel from this reactor is returned to its manufacturer in the United States.

The amount of used nuclear fuel from a research reactor, such as the SLOWPOKE, is typically less than a kilogram, a very small amount compared to the approximately 19.2 kilograms of uranium in a single CANDU fuel bundle. Nevertheless, research reactor fuel is an important component of Canada's used fuel inventory and it will be incorporated into the long-term management approach.

1. Bruce NGS – Kincardine, ON
2. Pickering NGS – Pickering, ON
3. Darlington NGS – Clarington, ON
4. Gentilly 2 NGS – Bécancour, PQ
5. Point Lepreau NGS – Musquash, NB
6. McMaster University – Hamilton, ON
7. École Polytechnique – Montréal, PQ
8. Dalhousie University – Halifax, NS
9. Saskatchewan Research Council – Saskatoon, SK
10. University of Alberta – Edmonton, AB
11. Royal Military College – Kingston, ON
12. AECL CRL – Chalk River, ON
13. AECL Douglas Point – Kincardine, ON
14. AECL Gentilly 1 – Montréal PQ
15. AECL Whiteshell Labs – Pinawa, MB

APPENDIX 8 /
REPROCESSING, PARTITIONING AND TRANSMUTATION

Reprocessing and the current status of partitioning and transmutation technologies were considered in our study in light of the ongoing international work to understand the potential of these processes for managing used nuclear fuel in the long term. Our research into these areas throughout our study was further motivated by the high level of interest registered by Canadians in knowing more about the potential to "recycle" or "reuse" used fuel, options we have come to expect in many other areas of our life. Interested in opportunities to "recycle" in the context of used nuclear fuel, and intrigued by international work on transmutation as a potential for reducing the long-term hazard of used nuclear fuel, Canadians expressed a desire for the NWMO to report back on our findings and determinations concerning these options. (See NWMO background papers on reprocessing, partitioning and transmutation available at www.nwmo.ca/partitioningandtransmutation and www.nwmo.ca/implicationsrpt).

Reprocessing is the application of chemical and physical processes to used nuclear fuel for the purpose of recovery and recycling of fissionable isotopes.

Most of the existing used fuel in the world was produced in Light Water Reactors, not used in Canada. This used fuel contains a significant amount of fissile material, twice as much as natural uranium. Thus, it has always been recognized that used fuel offers the potential for recycling. Indeed, of the 260,000 tonnes of used power reactor fuel produced to date, about one-third (85,000 tonnes) has already been reprocessed in large commercial facilities to recover the uranium and plutonium for eventual recycling. These facilities are located mostly in Europe, and can reprocess about 40 percent of the used fuel arising from these power reactors. However, for reasons largely related to weapons proliferation concerns, the United States government has banned domestic commercial reprocessing since 1977, while pursuing research on more proliferation-resistant processes.

Reprocessing technology was first developed 60 years ago to extract weapons-grade plutonium-239 for the nuclear weapons programs of the United States, the United Kingdom and Russia, and later in the military programs of countries such as France, China and India. This initial military-related interest has significantly influenced the choice of fuel cycle-related infrastructure subsequently used by civilian nuclear power programs in these and other countries.

Reprocessing can take place after the used nuclear fuel is removed from the reactor and is allowed to cool for a number of years. The fuel is moved in large lead and steel casks to a reprocessing facility. There, it is dissolved in nitric acid while the volatile radioactive elements are mostly contained. Several separation and segregation processes are then used to isolate the different streams of products including uranium, plutonium, highly radioactive liquid waste; and less radioactive solids, liquids and gases. Reprocessing simply rearranges the components of the used nuclear fuel, but does not reduce the overall quantity or toxicity.

For a number of reasons, reprocessing as a management approach for used nuclear fuel is considered to be highly unlikely as a viable option for Canada at this time. The necessary facilities are very expensive, and inevitably produce residual radioactive wastes that are more difficult to manage than used nuclear fuel in its un-reprocessed form. Reprocessing also requires a commitment to an expanded and multi-generational nuclear fuel cycle, and it potentially separates out weapons-grade material (plutonium) in the course of the process.

At present, Canadian reactors use a once-through fuel cycle and thus far there has been no need for Canada to reprocess used nuclear fuel. Nevertheless, it is recognized that other fuel cycles aimed at the optimum use of uranium and/or plutonium could at some point be implemented in Canada and that some of these fuel cycles could involve reprocessing. While there is no purely technical obstacle to reprocessing, the abundant reserves of natural uranium in Canada suggest that it is unlikely Canada will implement reprocessing in the near future. Canada is a leader in uranium mining, and Canadian uranium reserves are far from being depleted. The cost of reprocessing is quite high, and is not about to be exceeded in the near future by the cost of mined natural uranium.

Power reactors in Canada use the CANDU system. Because of the specific composition of used CANDU fuel, there would be very little incentive to reprocess used fuel in Canada in the foreseeable future if the sole purpose was to recover the uranium. In fact, the uranium recovered from used CANDU fuel would be similar in isotopic composition to the low-level wastes arising from the light water fuel enrichment process (i.e., depleted uranium). Our used fuel thus contains very little fissile material, much less than natural uranium, and the only economic incentive for recycling would be to recover the small amounts of plutonium it contains (about 0.3 percent). Our cost estimates, based on extrapolation from the light water reactor reprocessing costs (the 'Harvard' study), suggest that reprocessing used fuel from CANDU reactors could increase the cost of nuclear electricity by as much as 20 percent if no credit is taken for the recycling of the plutonium. Even with a credit for recycle, the reprocessing option would add five to ten percent to the cost of electricity, as much if not more than the entire cost of waste disposal and reactor decommissioning.

On the other hand, it must be acknowledged that economic conditions could be much different in 50 or 300 years. Waste management approaches that ensure accessibility to the used fuel for a sufficiently long time would provide the adaptability and flexibility to enable future generations to make decisions on the case for reprocessing in the future.

The cost of building the necessary industrial capacity to undertake reprocessing and the need to commit to an expanded and multi-generational nuclear fuel cycle are significant limitations for Canada. With this technology, there would still be radioactive wastes to manage and reprocessing would increase the types of wastes and the risks of spreading technology that could be used for production of nuclear weapons material. Reprocessing used fuel is potentially economically feasible, but only in the case of a continuing nuclear fission reactor program in Canada.

Reprocessing and recycling of the plutonium recovered from used CANDU fuel would eliminate the most active component of the wastes (plutonium-239) after 1,000 years, and would thus reduce the long-term toxicity of some of the wastes. Eventually, a process called **partitioning and transmutation** using nuclear reactions initiated by neutrons, protons, or even photons from lasers may be able to transform some of the other radioactive components (not plutonium or uranium) which have been separated through reprocessing and partitioning into non-radioactive elements, or into elements with shorter half-lives, which would be hazardous for a shorter period of time. The partitioning step involves a series of physical and chemical separation processes similar to reprocessing. The transmutation step involves the conversion of one element into another by means of particle bombardment.

If in the future there were a decision to further process CANDU fuel for the purpose of reducing the volume of high-level radioactive waste and toxicity of the fuel, there would need to be significant advances in the area of partitioning and transmutation. As opposed to reprocessing, which is routinely carried out on a commercial scale, partitioning and transmutation is still in its early developmental stage. Introduction of partitioning and transmutation on a commercial scale would require an additional process step at the back-end of the nuclear fuel cycle and a commitment to the continued use of nuclear energy by current and future generations. Exposure risk would increase appreciably due to the complexity of the fuel cycle and the multiple processing steps involved in partitioning and transmutation. As is the case for reprocessing, there would be further risk of spreading technology that could be used for production of nuclear weapons material. Costs are very difficult to determine, and the time-frame for investments would span many decades, imposing financial limitations with uncertain outcomes. While partitioning and transmutation might reduce the volume and the toxicity of the used nuclear fuel to be managed, it would not avoid the requirement for long-term management of the residual high-level radioactive wastes that would be produced.

Transmutation, now in the research phase, has the potential to completely eliminate some fission products and long-lived minor actinides thereby rendering them harmless. Well-funded research and development programs including experimental accelerator driven transmutation facilities are underway in Europe, Japan, the United States, China, Russia, South Korea and other countries. Partitioning and transmutation continue to be the subject of considerable study internationally, in particular in France, where substantial funds have been devoted over the past several years to examining the feasibility of partitioning and transmutation as a complementary option for managing used fuel in the future. Based on this research, the scientific and technical foundation is not yet sufficiently advanced for implementation and long-term management of the residual materials would still be required. In a recent report from France, the Autorité de sûreté nucléaire française (French Nuclear Safety Commission), reported that *"industrial implementation of transmutation cannot be foreseen until the years 2040 – 2050 at best."*

The possibility of transmuting various radioactive elements has only been demonstrated in the laboratory. As it is too soon to demonstrate that it would be commercially feasible with the volume of used nuclear fuel that exists in Canada, we recommend keeping a "watching brief" on the findings concerning partitioning and transmutation. Systematic monitoring of this technology and other areas of evolving scientific research will continue to be an important function of the NWMO to stay abreast of current developments concerning the long-term management of used nuclear fuel.

APPENDIX 9 / METHODS SCREENED OUT

The *Nuclear Fuel Waste Act* requires the NWMO to study approaches based on three methods for the long-term management of used nuclear fuel: deep geological disposal in the Canadian Shield; storage at nuclear reactor sites; and centralized storage, above or below ground.

Methods Receiving International Attention

The first NWMO discussion document, *Asking the Right Questions*, identified 11 other methods that have been advanced in the past by governments, industry and researchers. The NWMO Assessment Team did not include these additional methods in its preliminary assessment. However, it did suggest keeping a "watching brief" on three methods receiving international attention. The following discussion is excerpted from the NWMO document *Understanding the Choices*.

Reprocessing, Partitioning and Transmutation involve chemical and physical processes to recover and recycle the fissionable isotopes in used nuclear fuel. Reprocessing facilities are very expensive and inevitably produce residual radioactive wastes that are more difficult to manage than used nuclear fuel in its un-reprocessed form. This option requires a commitment to an expanded and multi-generational nuclear fuel cycle, and it potentially separates out weapons usable material in the course of the process.

Eventually, the process called transmutation may make it possible to transform some of the radioactive components which have been separated through reprocessing and partitioning into non-radioactive elements, or into elements with shorter half-lives. Current science for transmutation is in its infancy, and it is too soon to demonstrate that it would be commercially feasible in Canada. Transmutation would not solve the problem of managing nuclear waste; it would still require a method for the long-term management of residual materials or radioactive and toxic components that could not be transformed.

In France, a country that has maintained a significant research program on transmutation, the Director of the Nuclear Safety Commission recently stated, "industrial implementation of transmutation cannot be foreseen until the years 2040 to 2050 at best." In the United Kingdom, the Committee on Radioactive Waste Management recently decided that partitioning and transmutation did not seem promising, at least given current knowledge, and they have proposed to screen it out as an option for the United Kingdom.

Deep Borehole Placement involves placing used fuel packages at depths of several kilometres in boreholes with diameters of typically less than one metre. Packages would be stacked on top of one another in each borehole, separated by layers of bentonite or cement.

Although very deep borehole placement may hold some potential as a method for the disposal of small quantities of radioactive waste, it would be difficult to implement and ensure isolation and containment of larger quantities of used nuclear fuel.

The concept of an **International Repository**, which would involve the transboundary movement of used nuclear fuel, does not contravene any international treaty. However, most countries subscribe to the self-sufficiency principle under which they are responsible for any waste they produce. An international repository may become more attractive for some countries in future years, but it is not a decision to be made solely by Canada. Canada could maintain some currency in this area by co-ordinating with other countries and international agencies that are following this option.

Methods of Limited Interest

The following used nuclear fuel management methods have been investigated to varying degrees over the past 40 years and in some cases are still being advocated by a few individuals or organizations. None are being implemented anywhere, nor are they part of any national research and development program. Some are contrary to international conventions. The methods of limited interest and the reasons for screening them out are shown in Table A9-1.

The following discussion of these methods of limited interest is adapted from the NWMO document *Understanding the Choices*, Appendix 4 / Screening Rationale for Methods of Limited Interest.

Dilute and Disperse differs from all other used nuclear fuel management methods in that there would be no containment of the waste and isolation from the environment. One method involves dissolving used nuclear fuel in acid, neutralizing the solution and discharging it slowly down a pipeline into the sea. Another possibility would be to transport the used fuel solution by tanker to the open ocean and release it there. The discharge site and rate would be such that radiation doses to people would never exceed internationally accepted limits.

This method has never seriously been proposed for used nuclear fuel because sea disposal is prohibited by international conventions. Dilute and disperse is not included in any national or international research and development programs.

Disposal at Sea would involve placing packaged used nuclear fuel on the bed of the deep ocean. The packaging would consist of canisters designed to last for a thousand years or more. The used fuel would be in a solid form that would release radionuclides into the ocean very slowly when the canisters fail. The site would be one where the water is a few kilometres deep, so that the used fuel would not be disturbed by human activities and there would be substantial dilution of radionuclides before they reach the surface environment.

Sea disposal was investigated by the Nuclear Energy Agency's Seabed Working Group. It would be an extension of the 'sea dumping' method which was used for disposal of solid low level radioactive waste until the early 1980s and which is now prohibited under international conventions. Sea disposal is prohibited by international conventions and is not included in any national or international research and development programs.

Disposal in Ice Sheets would involve placing containers of heat-generating used nuclear fuel in very thick, stable ice sheets, such as those found in Greenland and Antarctica. Three concepts have been suggested. In the "meltdown" concept, containers would melt the surrounding ice and be drawn deep into the ice sheet, where the ice would refreeze above the used fuel containers creating a thick barrier. In the "anchored emplacement" concept, containers would be attached by surface anchors that would limit their penetration into the ice by melting to around 200-500 metres, thus enabling possible retrieval for several hundred years before surface ice covers the anchors. Lastly, in the "surface storage" concept, containers would be placed in a storage facility constructed on piers above the ice surface. As the piers sank, the facility would be jacked up to remain above the ice for perhaps a few hundred years. Then the entire facility would be allowed to sink into the ice sheet and be covered over.

There has been very little work on disposal in ice sheets because there has never been enough confidence about predicting the fate of the used nuclear fuel and because of the potential for release of radionuclides into the ocean. Disposal of radioactive waste in Antarctica is prohibited by international treaty and Denmark has indicated that it would not allow such disposal in Greenland. Disposal in ice sheets is not included in any national or international research programs.

Table A9-1 Methods of Limited Interest

METHOD	CONTRARY TO INTERNATIONAL CONVENTIONS	INSUFFICIENT PROOF-OF-CONCEPT
Dilution & Dispersion	X	X
Disposal at Sea	X	X
Disposal in Ice Sheets	X	X
Disposal in Space		X
Rock Melting		X
Disposal in Subduction Zones		X
Direct Injection		X
Sub-Seabed Disposal		X

Disposal in Space would permanently remove the used nuclear fuel from the Earth by ejecting it into outer space. Destinations that have been considered include the sun and ejection beyond the solar system. This method has been suggested for disposing of small amounts of the most toxic waste materials.

Space disposal has never been included in any major research and development program. Considerable further processing of the used nuclear fuel would be required. Concerns about the risk of an accident have been reinforced by the U.S. Space Shuttle Challenger and Columbia accidents.

Rock Melting would involve placing the used nuclear fuel in liquid or solid form in an excavated cavity or a deep borehole. Heat generated by the used fuel would then accumulate, resulting in temperatures sufficient to melt the surrounding rock and dissolve the radionuclides in a growing sphere of molten material. As the rock cools, it would crystallize and incorporate the radionuclides in the rock matrix, thus dispersing the used fuel throughout a larger volume of rock. In a variation of this method, the heat generating waste would be placed in containers, causing the rock around the containers to melt, sealing the used fuel in place. Research was carried out on this method in the late 1970s and early 1980s, when it was developed to the level of engineering design. The design involved a shaft or borehole that led to an excavated cavity at a depth of two to five kilometres. It was estimated, but not demonstrated, that the used nuclear fuel would be immobilized in a volume of rock one thousand times larger than the original volume of the used fuel. Another early proposal was to use weighted containers of heat-generating used fuel that would continue to melt the underlying rock, allowing them to move downwards to greater depths with the molten rock solidifying above them.

There was renewed interest in rock melting in the 1990s in Russia, particularly for the disposal of limited volumes of specialized material such as plutonium. Russian scientists have also proposed that used nuclear fuel could be placed in a deep shaft and immobilized by a nuclear explosion, which would melt the surrounding rock. There have been no practical demonstrations that rock melting is feasible or economically viable. This method is not being investigated in the national program of any country.

Disposal in Subduction Zones would involve placing used nuclear fuel in a subducting or descending plate of the earth's crust. As subduction zones are invariably offshore, this concept can also be considered as a variant of placement in the sea or beneath the seabed. Either tunneling or deep sub-seabed boreholes could theoretically be used to emplace the used nuclear fuel close to an active subduction zone. Free-fall penetrators could also be used.

Disposal of used nuclear fuel in subduction zones has not received significant attention by the radioactive waste management community in Canada or abroad for several reasons. Potential sites for such a disposal facility are very limited and offshore. Transportation distances would be significant. Monitoring and retrieval of used fuel would be more difficult compared with deep geologic repositories. And there is concern about the fate of used nuclear fuel buried in subduction zones and whether it might return to the surface environment via volcanic eruptions. It has also been suggested by some that this method could be seen as a form of sea disposal and hence would be prohibited by international conventions.

Direct Injection would involve the injection of liquid radioactive waste directly into a layer of rock deep underground. Although used for the disposal of liquid hazardous and low-level waste in the U.S. in the past, this technique has only ever been used for liquid high-level waste in the former Soviet Union, at a number of locations usually close to the waste generating sites.

Direct injection requires detailed knowledge of subsurface geological conditions, as it does not incorporate any man-made barriers. There would be no control of the injected material after disposal and retrieval would be impossible. There are many technical unknowns that would require extensive research to gain the degree of confidence that this method would be appropriate for a specified site. Although the option would not contravene international conventions, it would not be consistent with the spirit of international guidance on the long-term management of used nuclear fuel. Current published assessments indicate no substantive advantages of this method and it is not being pursued in any country as a means of dealing with an entire national inventory of used nuclear fuel.

Sub-Seabed Disposal would involve burial of used nuclear fuel containers in a suitable geological setting beneath the deep ocean floor. The disposal sites would be ones where the sediments are plastic and have a high capacity to absorb radionuclides, and where the water is a few kilometres deep. The main sub-seabed disposal concept would use missile-shaped canisters called "penetrators" that hold the solid waste, are dropped from ships, and bury themselves to a depth of a few metres or more in the sediments on the ocean floor. The idea behind the concept is that the waste form, inner canister, penetrator and sediments would provide sufficient protection to prevent the release of radionuclides into the ocean for thousands of years or more. When release finally does take place, it would occur very slowly and there would be substantial dilution. Another variation of this option would use deep sea drilling technology to stack used nuclear fuel packages in holes drilled to a depth of 800 metres, with the uppermost container about 300 metres below the seabed. An alternative "sub-seabed" option would be to access a location deep beneath the ocean floor via on-land shafts and drifts. In this instance, the ocean itself would serve as a last line of defense. The theory is that if contaminants were to escape and move to the ocean environment, their volume would be small and the buffering and diluting capacity of the ocean would mitigate the consequences.

Sub-seabed disposal was investigated extensively in the 1980s, primarily under the auspices of the Seabed Working Group set up by the Nuclear Energy Agency (NEA) of the Organization for Economic Co-operation and Development (OECD). Canada participated in this group, as did the United States., the United Kingdom., Japan and several European countries. Research on sub-seabed disposal effectively ceased when it became clear that there would always be intense political opposition. Ocean access to a sub-seabed repository is now prohibited by international conventions.

APPENDIX 10 / NUCLEAR WASTE MANAGEMENT IN OTHER COUNTRIES

Thirty-two countries in the world use nuclear energy to generate electricity. Together they operate more than 400 nuclear power reactors. Decision-making about long-term used fuel management is at different stages in each country. Some, like Canada, France and the United Kingdom, are reviewing options and approaches for the long-term management of used nuclear fuel. Others, like Switzerland and Japan, are in the early stages of site selection for deep geological repositories. A few, like Finland, the United States and Sweden, are in the latter stages of decision-making. A number of countries have postponed consideration of the issue, or have no plans.

Table A10-1 International Nuclear Waste Management Programs

Country	Reactors	Intermediate Storage	Long-term Management
Canada	**22**	Used fuel is stored in wet and dry interim storage facilities at the nuclear generating stations.	NWMO studies approaches for long-term management, and its recommendations go to government in November 2005 for review and subsequent decision by the government.
Finland	**4**	Interim storage of spent fuel is at the nuclear generating stations in either water pool or dry storage facilities (CASTOR-type cask).	In 1983 the government established guidelines for long-term management of nuclear waste in Finland, including interim milestones for progress towards disposal "in an irrevocable manner." Following a site selection process and agreement by the host community, Parliament approved a site for a spent fuel disposal facility in 2001; construction of an underground rock characterization facility started in mid-2004; and the licence process for the repository is scheduled to start in 2012.
France	**59**	Spent nuclear fuel is first stored in water at the reactor site, it is then transported to a pool-type, away-from-reactor facility at the La Hague reprocessing plant (operated by Cogema) until it is reprocessed. The plutonium recovered is recycled into mixed-oxide fuel (MOX). High-level waste is vitrified and stored at Cogema's facilities.	In 1991 the French government established a 15-year research program into three main areas of study: • Research on partitioning & transmutation; • Options for retrievable or non-retrievable disposal in deep geologic formations; • Conditioning and long-term surface storage techniques for the waste. A global evaluation report on these three areas of research will be issued by the end of 2005; the government will submit a report on a proposed strategic direction early in 2006 for consideration by the French Parliament.
Germany	**18**	Previously, after storing used fuel in water filled pools to cool, utilities were required to either send the used fuel for reprocessing, or send the fuel (and the vitrified wastes from reprocessing) to a centralized interim storage facility. Germany has four 'centralized' and one 'on-site' interim storage facilities. As of December 2003 all nuclear power plants have approval for on-site interim storage of spent fuel. Reprocessing is to be terminated by July 1 2005.	The new Atomic Energy Act came into force in 2002; construction of new nuclear power plants is prohibited and the use of existing plants is limited. A working group developed recommendations on a selection procedure for a final disposal site, which the Federal Government is currently reviewing. The aim is for an operational final storage site, for all radioactive waste, to be available as of 2030.
India	**14**	Stored in wet pools; then reprocessed.	Repository planned but not sited.
Japan	**53**	Used fuel stored on site before being sent abroad for reprocessing; domestic reprocessing plant being built.	Siting process underway to seek volunteer community for deep geological repository for disposal of wastes arising from reprocessing.

Table A10-1 (cont'd) International Nuclear Waste Management Programs

Country	Reactors	Intermediate Storage	Long-term Management
Korea	**18**	Stored at reactor sites; work underway to establish spent fuel dry storage systems at 4 NPP; Korea recently decided to separate the sites for a low and intermediate level radioactive waste disposal facility and the site for a spent fuel interim storage facility; plans for a centralized interim facility by 2016.	In 1997 the Korean Atomic Energy Commission adopted a research and development plan for high-level radioactive waste (HLW) disposal. Currently work is ongoing to finalize the Korean repository concept for HLW disposal and to undertake a system performance assessment. The combined research output will be submitted to the government to guide the development of a national policy for HLW disposal.
Russia	**27**	Used fuel is reprocessed; uranium is recycled; plutonium stored for future use.	Four geological disposal facilities are planned to begin operation in 2025-2030.
Sweden	**11**	Used fuel is transported via ship and stored at CLAB, a centralized, interim underground wet storage facility.	Following years of research and feasibility studies the Swedish government endorsed a plan in 2001 for site selection for a deep geological repository. Investigations on two sites began in 2002; selection of a prefered site by 2008; an application for a repository is expected by 2010, with a target for operations around 2017.
UK	**31**	Used fuel is reprocessed; vitrified wastes stored above ground for 50 years.	The government established a new organization (CoRWM) in 2003 to investigate options for long-term management approach and recommend the best option, or combination of options in 2006. Work to date has produced a short-list of options to be taken forward for detailed assessment.
USA	**104**	Used fuel stored at reactor sites.	Construction licence application being prepared for deep geological repository at Yucca Mountain, Nevada. The U.S. Department of Energy is planning to submit a licence application perhaps in 2005 or 2006.

A more complete review of international waste management programs is contained in the NWMO Background Paper 7-6, "A Comparative Overview of Approaches to Management of Spent Nuclear Fuel and High Level Wastes in Different Countries" Charles McCombie, Bengt Tveiten www.nwmo.ca/internationalapproaches

APPENDIX 11 / REGULATORY FRAMEWORK

The legal and administrative arrangements governing nuclear energy have evolved considerably since the industry's inception immediately after World War II. The Government of Canada has legislative authority over the development and control of nuclear energy in Canada. The industry is regulated both through laws of general application and through specially focused regulations, policies and licence provisions. Consultation and cooperation among provincial, national and international agencies is essential to promote harmonized regulation and consistent national and international standards and achieve conformity with the measures of control and international obligations to which Canada has agreed concerning radioactive waste.

Federal Legislation

Nuclear Fuel Waste Act

The aim of the *Nuclear Fuel Waste Act* (*NFWA*) is to provide the necessary framework for choosing and then implementing a long-term management approach for nuclear fuel waste in Canada that is comprehensive, integrated and economically sound. It has five major sections addressing: the creation and function of the waste management organization; financing; the study produced by the waste management organization; reports, approvals and inspections; and offences and punishment.

The *NFWA* requires the establishment of the NWMO to conduct a study and present the Government of Canada with potential approaches and realistic recommendations for the management of nuclear fuel waste. The NWMO is to present its study within three years of the act coming into force, to the Minister of Natural Resources Canada. The Minister may seek public comment on the study, or request the NWMO to undertake further work, before providing a recommendation to the government.

Once the government decides on the approach for long-term management of used nuclear fuel the NWMO is required to implement that approach. Changes with respect to reporting and financing take effect.

Nuclear Safety and Control Act

The Canadian Nuclear Safety Commission (CNSC) is the regulatory body established by the federal government to licence nuclear facilities and to regulate the use of nuclear energy and materials to protect health, safety, security and the environment and to respect Canada's international commitments on the peaceful use of nuclear energy. The CNSC operates and enforces regulations under the *Nuclear Safety and Control Act* (NSCA). The CNSC is the nuclear energy and materials "watchdog" in Canada. The Commission is responsible for regulating nuclear power plants, nuclear research facilities and many uses of nuclear materials, including the use of radioisotopes for the treatment of cancer, and the operation of uranium mines and refineries.

The CNSC mandate involves:

- Regulating the development, production and use of nuclear energy in Canada;
- Regulating the production, possession and use of nuclear substances, prescribed equipment and prescribed information;
- Implementing measures respecting international control of the use of nuclear energy and substances, including measures respecting the non-proliferation of nuclear weapons; and
- Disseminating scientific, technical and regulatory information concerning the activities of the CNSC.

Requirements of Licencees

All current nuclear facilities – including provisions for nuclear waste management – must be licenced by the CNSC. The CNSC requires licence applicants to conduct detailed analyses of the anticipated effects on the environment, and on human health, safety and security of the proposed licenced activity. It also requires applicants to conduct a public information program that provides this information to persons living in the vicinity of the site in a clear and understandable manner.

As part of the review process, the CNSC evaluates the detailed submissions of the applicant, including the public information program. In addition, and to facilitate openness and transparency, the CNSC makes decisions on the licensing of major nuclear facilities through a public hearing process. The CNSC notifies and encourages individuals and organizations to attend public hearings, and to make submissions orally or in writing. Advance notice of the hearings is published in newspapers and notice of hearings and meetings is posted on the CNSC website (www.nuclearsafety.gc.ca). A detailed record of proceedings, including the reasons for decisions of the Commission, is made available to the public shortly after the proceedings. The CNSC also administers the *Nuclear Liability Act*, including designating nuclear installations and prescribing basic insurance to be carried by the operators.

To transport used nuclear fuel, a proponent (the consignor) must obtain a licence that contains, in addition to the information required by the Packaging and Transport of Nuclear Substances Regulations of the *Nuclear Safety and Control Act*, a detailed transportation security plan. The information required for the plan includes, but is not limited to:

- A threat assessment;
- Proposed security measures; and
- Arrangements for a response force.

Before a licence is issued, the security plan submitted with the licence application is reviewed by CNSC staff to ensure compliance with the regulations and a "best-practices" approach to the security arrangements.

CNSC Regulatory Documents

As the federal regulator, the CNSC executes licensing decisions made by the Commission or its designates, and continually monitors licencees to ensure they comply with safety requirements that protect workers, the public, and the environment and uphold Canada's international commitments on the peaceful use of nuclear energy. The requirements are set out through the *NSCA*, its associated regulations, licences and directives provided by the CNSC. The CNSC also offers instruction, assistance and information on these requirements in the form of regulatory documents, such as policies, standards, guides and notices. Compliance is verified through inspections and reports.

CNSC Regulatory Policy P-290, Managing Radioactive Waste

Regulatory policies are documents that describe the philosophy, principles or fundamental factors which underlie the CNSC's approach to its regulatory mission. They provide direction to CNSC staff and information to stakeholders.

Regulatory Policy P-290 "Managing Radioactive Wastes" describes the philosophy that underlies the CNSC's approach to regulating the management of radioactive waste and the principles that are taken into account when making a regulatory decision concerning radioactive waste management. It is intended to promote the implementation of measures to manage radioactive waste so as to protect the health and safety of persons and the environment, provide for the maintenance of national security, and achieve conformity with measures of control and international obligations to which Canada has agreed; and to promote consistent national and international standards and practices for the management and control of radioactive waste.

When making regulatory decisions concerning the management of radioactive waste, the CNSC will consider the extent to which the owners of the waste have addressed the following principles:

- The generation of radioactive waste is minimized to the extent practicable by the implementation of design measures, operating procedures and decommissioning practices;
- The management of radioactive waste is commensurate with its radiological, chemical and biological hazard to the health and safety of persons and the environment and to national security;
- The assessment of future impacts of radioactive waste on the health and safety of persons and the environment encompasses the period of time when the maximum impact is predicted to occur;
- The predicted impacts on the health and safety of persons and the environment from the management of radioactive waste are no greater than the impacts that are permissible in Canada at the time of the regulatory decision;
- The measures needed to prevent unreasonable risk to present and to future generations from the hazards of radioactive waste are developed, funded and implemented as soon as reasonably practicable; and
- The transborder effects on the health and safety of persons and the environment that could result from the management of radioactive waste in Canada are not greater than the effects experienced in Canada.

CNSC Draft Regulatory Guide G-320, Assessing the Long-term Safety of Radioactive Waste Management

Regulatory guides are documents that indicate acceptable ways of meeting CNSC requirements as expressed in the Act, Regulations, regulatory standards or other legally-enforceable instrument. They provide guidance to licencees and other stakeholders.

The purpose of Draft Regulatory Guide G-320 "Assessing the Long-term Safety of Radioactive Waste Management" is to assist licencees and applicants assess the long-term safety of storage and disposal of radioactive wastes. Long-term safety assessments are used to give reasonable assurance that proposed plans for the long term management of radioactive waste are consistent with CNSC requirements for protecting the health and safety of humans and protecting the environment.

Draft Regulatory Guide G-320 sets out typical ways to assess the impacts that radioactive waste storage and disposal methods have on the environment and on the health and safety of people in the long term. It provides guidance on such matters as:

- Assessment methodologies, structure and approach;
- Level of detail of assessments;
- Confidence to be placed in assessment results;
- Applying radiological and non-radiological criteria;
- Defining critical groups for impact assessments;
- Selecting time frames for impact assessments;
- Setting post-decommissioning objectives;
- Long term care and maintenance considerations, and
- Use of institutional controls.

The approaches described are possible methods of providing reasonable assurance of long-term safety. They are not equally applicable to every assessment, licence applicants are expected to propose and justify their application of the guidance provided.

Compliance Verification

Confirmation of compliance with licences is managed within the CNSC's formal compliance verification program that includes promotion, verification and enforcement.

A compliance promotion program informs the regulated community of the rationale behind the regulatory regime and disseminates information about regulatory requirements and standards.

To verify compliance, the CNSC regularly evaluates the licencee's operations and activities, ensures that administrative controls are in place, reviews, verifies and evaluates information provided and evaluates any remedial action to ensure that incidents are avoided in the future. Routine inspections, evaluations and audits are supplemented by analysis of safety-significant events.

The CNSC uses a graduated approach to enforcement, commensurate with the risk or regulatory significance of the violation.

Canadian Environmental Assessment Act

Canadian laws of general application that are relevant to aspects of the management of used nuclear fuel include the *Canadian Environmental Assessment Act*. An environmental assessment is required prior to the initial issuance of licences by the CNSC that authorize activities involving nuclear substances. Since all of the aspects involved in managing nuclear waste, including interim and long-term storage and disposal and any transportation between, must be authorized through issuance of a CNSC licence, each of these aspects must be considered in the environmental assessment of the project. Certain projects, as defined by the Comprehensive Studies List Regulations, are required to be subject to a comprehensive study. The environmental assessment must be conducted "as soon as practicable in the planning stages and before irrevocable decisions are made."

Provincial and Territorial Legislation

Although Canada's constitutional division of power confers the authority to regulate nuclear energy to the federal government, it does not exclude provincial and territorial authority to regulate related matters within the provincial domain.

With the exceptions of Nova Scotia and Ontario, and some ambiguity in Saskatchewan, all provinces and territories include nuclear substances in the scope of legislation and regulations addressing the transportation of dangerous goods. Some provincial jurisdictions also include radioactive waste in the scope of legislation addressing waste management.

International Treaties and Conventions

Canada also participates actively in the conventions and standards development led by the United Nations' International Atomic Energy Agency (IAEA). The IAEA serves as the global focal point for nuclear cooperation, assisting member countries in planning for and using nuclear science and technology for various peaceful purposes.

Among other roles, the IAEA develops nuclear safety standards and, based on these standards, promotes the achievement and maintenance of high levels of safety in applying nuclear energy, as well as in protecting human health and the environment against ionizing radiation.

The IAEA also verifies, through its inspection system, that member countries comply with their commitments under the Treaty on the Non-Proliferation of Nuclear Weapons, to use nuclear material and facilities for peaceful purposes only.

In addition to the *Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste*; and the *Treaty on the Non-Proliferation of Nuclear Weapons*, Canada is involved in a number of international agreements that address nuclear waste management, including:

- The Convention on the Physical Protection of Nuclear Material;
- The Convention on Nuclear Safety;
- The Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter; and
- The Antarctic Treaty.

The above treaties, conventions and agreements provide a general framework of considerations within which Canada is committed to operate.

Table A11-1 lists the key federal legislation that provides the overarching legal and administrative framework governing used nuclear fuel in Canada.

Table A11-1 Key Federal Legislation Governing Nuclear Waste in Canada

LEGISLATION	SIGNIFICANCE
Legislation Related to Nuclear Substances	
Nuclear Energy Act, 1997	Legislative framework for development and utilization of nuclear energy.
Nuclear Safety and Control Act, 1997	Establishes the CNSC to replace the AECB to regulate the use of nuclear energy and materials to protect health, safety, security and the environment and to respect Canada's international commitments on the peaceful use of nuclear energy.
Nuclear Liability Act, 1997	Creates obligation for nuclear operators to prevent injury to health, or damage to property, from nuclear material at the facility (or while it is being transported).
Nuclear Fuel Waste Act, 2002	Establishes the NWMO; requires financing mechanism to fund nuclear fuel waste management over the long term.
Legislation Related to Nuclear Substances	
Canadian Environmental Assessment Act, 1992	Requires an environmental assessment of new nuclear waste management facilities.
Transportation of Dangerous Goods Act, 1992	Nuclear substances are classed as "dangerous goods" and fall under this act and its regulations, unless exempted by the *Packaging and Transport of Nuclear Substances Regulations* under the *Nuclear Safety and Control Act.*
Canadian Environmental Protection Act, 1999	Governs environmental aspects of inter-provincial shipments of hazardous wastes and recyclable materials.

APPENDIX 12 / USED FUEL SCENARIOS

At the end of 2004, there were approximately 1.87 million used fuel bundles in Canada. The total number of used fuel bundles that will eventually be produced will depend on actual production values at each of the nuclear generating stations, decisions by the operators of nuclear generating stations on refurbishment of existing reactors, and whether or not new nuclear reactors are built in Canada.

In 2004, there were applications with the Canadian Nuclear Safety Commission (CNSC) for the refurbishment of nuclear power reactors in Ontario and New Brunswick, including the possibility of using new slightly enriched uranium (~ 1% uranium-235) in the CANDU reactors at Bruce. The proposed life extension at Bruce would extend its operational life to 2043. As a result, there is the potential for more used nuclear fuel with slightly different characteristics in Canada.

Decisions on refurbishment or new reactor builds will likely be made by the provincial governments in Ontario, Québec and New Brunswick, possibly in conjunction with the Government of Canada.

Reference Used Fuel Scenario

The conceptual designs and cost estimates for long-term management approaches, prepared for the Joint Waste Owners (JWO) of used fuel and submitted to the NWMO, are based on a projected inventory which assumes that the Pickering, Bruce and Darlington reactors in Ontario will operate 40 years, the Point Lepreau reactor in New Brunswick will operate 25 years, and the Gentilly reactor in Québec will operate 30 years. In this scenario, the existing reactors would be shut down after their respective 25, 30 and 40-year lifetimes. This reference scenario could be considered a gradual "phase out" for the existing fleet of reactors in Canada at the end of their life. The projected used fuel inventory was prepared in 2001 and estimated to be 3,557,451 bundles which were rounded up to 3.6 million bundles for conceptual design and cost estimating purposes.

In 2004, the JWO submitted summaries of cost estimates for the various long-term management approaches to the NWMO. These cost estimates were adjusted to reflect an updated estimate of the number of used fuel bundles that would be produced assuming an average nuclear reactor life of 40 years. This updated 2004 estimate is 3,665,094 fuel bundles or a rounded value of 3.7 million fuel bundles.

In 2005, the installed nuclear generation capacity in Canada consists of 22 reactors for a total of 16,000 MW, although several Ontario units are currently shut down. Based on previous operating experience, if all of these CANDU reactors were operational, they would generate approximately 100,000 used fuel bundles annually or about 6.25 bundles per MW year.

The projected number of bundles was also provided for an average station life of 30 years (3.0 million bundles) and an average station life of 50 years (4.4 million bundles), reflecting uncertainty in the projected future estimates.

The change in the reference scenario from about 3.6 million to 3.7 million fuel bundles (< 3%) would not have a significant impact on the conceptual designs for long-term management facilities. The larger value is more conservative from a design and cost perspective, but not materially different than the original estimate since the reference designs were prepared using the projected number of used fuel bundles rounded up to the nearest 100,000 bundles.

A reference used fuel scenario based on 3.6 (or 3.7) million used fuel bundles is considered to be a reasonable projection assuming that the existing fleet of nuclear reactors in Canada have an average operational life of 40 years.

In 1962, the first demonstration of commercial nuclear power in Canada began with the Nuclear Power Demonstration reactor in Rolphton, Ontario. The first unit of the Pickering A Nuclear Generating Station commenced operation in 1971. The last unit of the Darlington reactors in Ontario will potentially reach 40 years of operation in 2033. Therefore, the reference 3.6 million fuel bundle scenario represents about 70 years of CANDU nuclear reactor operation in Canada.

Other Used Fuel Scenarios

In 2004, the NWMO commissioned a third-party review of the conceptual designs and cost estimates for the various long-term management approaches submitted by the JWO. The report found that all of the conceptual designs have sufficient flexibility to accommodate increased used fuel capacity in the future by constructing either incremental additions or completely new facilities. Further discussions in 2004 between the NWMO and the JWO confirmed that the concepts were sufficiently robust to accommodate more or less used fuel bundles in the future, relative to the reference assumption of 3.6 million bundles.

The National Energy Board report on Canada's energy future looked at two plausible energy futures for Canada, both of which assume a growth in electrical generation of 1.8 percent per year until 2025:

1. **Supply Push** scenario assumes that energy technology advances gradually and Canadians take limited action to limit the impact on the environment. The main focus is maintaining security of energy supply and a push to develop known resources of energy in Canada. The Supply Push scenario would see a resurgence of coal-fired plants in addition to gas-fired generation, hydraulic and nuclear.

2. **Techno-Vert** scenario assumes that energy technology advances rapidly and Canadians take broad action to limit the impact on the environment by using environmentally friendly products and cleaner-burning fuels. The Techno-Vert scenario would see gas-fired generation, hydraulic and a shift towards cleaner coal burning technology, wind power and advanced nuclear reactors such as AECL's Advanced CANDU Reactor (ACR), which uses slightly enriched uranium.

The National Energy Board predicts a rise in Canada's electrical generating capacity from about 110,000 MW in 2000 to about 150,000 MW by 2025. For the Supply Push and the Techno-Vert scenarios, the electrical generation by nuclear power is assumed to be about 13 to 15 percent, respectively. Under the Techno-Vert scenario, installed nuclear generation capacity in Canada could rise from the current 16,000 MW to about 22,500 MW by 2025.

Assuming standard CANDU reactor technology, 22,500 MW of nuclear generation would produce about 140,000 used fuel bundles per year of operation in Canada.

The National Energy Board's report and the NWMO's discussions with Canadians over the past year have identified a need for the NWMO to explore future used fuel scenarios in addition to the reference "3.6 million bundle" scenario provided by the JWO. A number of other used fuel scenarios have been developed by the NWMO, which can be used for a high-level evaluation, and comparison with the reference used fuel scenario. They should be considered as "what-if" scenarios to test the robustness of the NWMO analysis of approaches for long-term management of used nuclear fuel. The scenarios have been designed to illustrate a broad range of future scenarios that include an "early" phase out of nuclear power and a continuing nuclear reactor program in Canada with a mixture of nuclear generation types.

Early Nuclear Phase Out

At the end of 2004, there were about 1.87 million used fuel bundles in Canada. With several reactors shut down, the production rate for used fuel is about 85,000 bundles per year. By the end of 2005, there is expected to be about 2 million bundles of used fuel in Canada. The nuclear reactors are assumed to be gradually shut down over a five-year period starting in 2007.

Under an early nuclear phase out scenario, the total used fuel inventory by 2012 is projected to be 2.5 million used CANDU fuel bundles distributed over the seven reactor sites in Canada. For the central facility long-term management options, the used fuel transportation period and the used fuel placement period are each reduced to 20 years.

Existing Reactor Refurbishment and Life Extension

Under the existing reactor refurbishment and life extension scenario, the existing fleet of CANDU reactors in Canada is assumed to continue operation until the reactors have reached an average life of 50 years. Most of the material would be standard used CANDU fuel, although there may be some bundles from the Bruce reactors with slightly enriched uranium. The number of bundles produced for this 50 year operating scenario is about 4.4 million. This used fuel inventory is assumed to be reached by 2043 when the last reactor unit at Darlington achieves 50 years of operation.

The number of reactor sites in Canada remains constant at seven. For the central facility long-term management options, the used fuel transportation period and the used fuel placement period are each increased to 40 years.

Continuing CANDU Nuclear Program

The continuing CANDU nuclear program scenario assumes the existing fleet of CANDU reactors continues operation and are refurbished or replaced with additional nuclear generation. While it is recognized that the used fuel could be a mixture of standard CANDU and slightly enriched uranium fuel, the used fuel inventory is conservatively based on standard CANDU bundles. The nuclear generation supply is based on maintaining nuclear power at 15 percent of the total energy supply in Canada (NEB 2003). Therefore, the current 16,000 MW of nuclear generation would increase to 22,500 MW by 2025.

Beyond 2025, energy supply and demand in Canada is uncertain. For the continuing CANDU nuclear program scenario, nuclear generation is assumed to remain constant at 22,500 MW for an additional 200 years, or roughly 3 times the current projected life of 70 years for commercial nuclear power production in Canada. Reprocessing of used fuel for reuse in future reactors is not assumed to occur due to the high cost of reprocessing CANDU fuel and the abundance of uranium resources in Canada. The used fuel inventory for the continuing CANDU nuclear program scenario is approximately 30 million bundles, two million as of 2005 and an additional 28 million by about 2200.

The number of reactor sites in Canada is assumed to increase from the current seven to ten sites. For the central facility long-term management options, the used fuel transportation period and the used fuel placement period are each increased to 250 years in order to maintain the currently assumed rate of handling 120,000 bundles per year.

Mixture of Continuing Nuclear Reactor Generation

The mixture of continuing nuclear reactor generation scenario maintains nuclear power at 15 percent of the total energy supply in Canada (NEB 2003). The current 16,000 MW of nuclear generation is assumed to increase to 22,500 MW by 2025 and remain constant for the next 200 years. Reprocessing of used CANDU fuel is not assumed for economic reasons.

For the mixed reactor scenario, nuclear generation in Canada is assumed to be a mixture of standard CANDU reactors with natural and slightly enriched uranium, Advanced CANDU Reactors and pressurized water reactors. The amount of used fuel produced over the next 200 years would depend on the exact mix of nuclear reactors and their operating periods, which is uncertain. However, the amount of used fuel produced can be reduced roughly by the uranium-235 enrichment factor. The fissile uranium-235 content in natural uranium is 0.7 percent; slightly enriched uranium fuel has 0.8 to 1.2 percent; Advanced CANDU Reactor fuel has about two percent and pressurized water reactor fuel has about four percent. As a result, some of these reactors may produce about one quarter to one half the used fuel of a standard CANDU reactor.

For the purposes of this future scenario, it is assumed that the future nuclear generation in Canada is dominated by Advanced CANDU Reactors and pressurized water reactors. The number of used fuel bundles (or equivalent bundles in the case of pressurized water reactors) produced in Canada by about the year 2200 is assumed to be 15 million bundles, or half the assumed inventory for the CANDU nuclear program scenario.

The number of reactor sites in Canada is assumed to increase from the current seven to ten sites. For the central facility long-term management options, the used fuel transportation period and the used fuel placement period are each assumed to be 250 years at a reduced handling rate of about 60,000 bundles (or equivalent) per year. Note that fuel enriched with uranium-235 has a higher burn-up and is consequently thermally hotter than used natural uranium fuel. In general, designs for used fuel containers have a thermal limit. Similar used fuel containers may hold less enriched fuel than natural uranium used fuel, depending on their cooling time out of reactor.

APPENDIX 13 / GLOSSARY

We offer this glossary to present and explain the terms and phrases that we have used in the course of this study. In some cases definitions are the same as used by others (Webster's dictionary; Canadian Nuclear Safety Commission, etc.) However in other cases they are different. We do this not to agree or disagree with other sources, but to provide clarity around our intent and our meaning.

Adaptive management is a combination of management, research, and monitoring so that credible information is gained and management activities can be modified by experience.

Biosphere is the environment where life exists.

Borehole is a hole drilled into the earth.

Cask is a mobile durable container for enclosing and handling nuclear fuel waste for storage and transport.

Centralized facility means a facility used for the extended storage or geologic placement of used nuclear fuel. The facility would be located at a single, central location and would accept used nuclear fuel from all reactor sites in Canada.

Communities of interest refers to interests that may be part of a given geographic community but whose reach may lie across many geographic locations. Such interests have a varying degree of "stake" in an issue that will be reflected in the degree to which social, economic and cultural effects are felt. For example, if the management strategy reaches on to Aboriginal traditional territory, the whole of the Aboriginal community in Canada will be watching with interest because what is done here will have implications well beyond in terms of the precedent it will set. Similarly, producers of nuclear waste across the world will be watching, as will the environmental community, the various faith-based communities, professional engineers, lawyers, and politicians at the federal, provincial, and local levels.

Container is the vessel into which the waste form is placed for handling, transport, storage and/or eventual disposal; also the outer barrier protecting the waste from external intrusions. The waste container is a component of the waste package.

Closure refers to administrative and technical actions directed at a repository at the end of its operating lifetime – for example covering the waste (for a near surface repository) or backfilling and/or sealing (for a geological repository and the passages leading to it) and termination or completion of activities in any associated structures.

Contingency (Financial) refers to an additional amount or percentage added to any cash flow item to cover reasonable variability in forecasts. Interest rates, inflation and other variables cannot be forecast with certainty. The size of a contingency is determined by the level of detail within a cash flow forecast and the level of risk mitigation that is required.

Crystalline rock is a generic term for igneous rocks and metamorphic rocks as opposed to sedimentary rocks.

Decommissioning is the closing of a nuclear station at the end of its life.

Deep Geological Disposal is the placement of used nuclear fuel deep underground where both natural and engineered barriers shield it from humans and the environment.

Deliberative survey is a public opinion research tool that provides people with background information and multiple perspectives to help inform the views they express.

Design life is the period during which a facility or component is expected to perform according to the technical specifications to which it will be or was engineered.

Dialogue brings people from all walks of life together and encourages them to work through difficult issues, learning from each other as they listen to and understand perspectives that are different from their own. Participants examine their own thinking, and through talking with each other, identify areas on which they can agree, while acknowledging differences.

Disposal is to manage used nuclear fuel in a manner that is conclusive, without the intention of retrieval or further use.

Dry storage is the interim placement of used fuel in specially engineered dry containers after its removal from wet storage pools.

Economic regions are broad-based geographic units based on census divisions and used for analysis of regional economic activity. There are 76 economic regions in Canada.

Escalator is the rate at which future costs are expected to grow on an annual basis. These figures are frequently tied to rates of inflation, but may be composed of a number of variables.

Flexibility refers to a ready capability to adapt to new, different or changing requirements.

Fissile refers to a nuclide that can be induced to fission by an incoming neutron. Only a few nuclides can fission (i.e., the splitting of a nucleus with the release of energy) and there is only one naturally occurring fissile nuclide, U-235. Other fissile nuclides are U-233 and some isotopes of plutonium (Pu-239 and Pu-241), but none of these occurs in nature to any appreciable extent.

Half-life is, for a radionuclide, the time required for the activity to decrease, by a radioactive decay process, by half.

Igneous rock is rock or mineral that solidified from molten or partly molten material.

Influence diagram is a tool used in multi-attribute analysis for mapping the principle interacting factors that influence the capacity of an option to perform well on a particular objective.

Isotopes are any two or more forms of an element having identical or very closely related chemical properties and the same atomic number but different atomic weights or mass numbers.

Joint Waste Owners (JWO) refers to corporations that own Canada's used nuclear fuel: Ontario Power Generation Inc., Hydro-Québec, NB Power Nuclear and Atomic Energy of Canada Limited.

Management approach is a strategy for the long-term care of used nuclear fuel which encompasses a particular technical method or sequence of methods, and the conditions necessary for its successful implementation, including societal requirements, related infrastructure, institutional and governance arrangements.

Mitigation refers to actions or measures undertaken with the objective to avoid, or reduce the severity of adverse impacts.

Multi-attribute utility-analysis methodology is a step-by-step decision support methodology that facilities a comprehensive assessment of various options against multiple objectives.

Ordovician sedimentary rock consists of shale and limestone bedrock formations that were laid down approximately 450 to 500 million years ago.

Partitioning is the separation and segregation of certain radioisotopes from used nuclear fuel.

Plutonic rock is intrusive igneous rock formed at considerable depth beneath the surface of the earth by cooling of magma.

Precautionary approach/principle (we use these expressions interchangeably) – a statement made to ensure that in decision-making, greater benefit of the doubt will be granted to the environment and to public health than to the activities that may be held to threaten these things. Its application recognizes that the absence of full scientific certainty shall not be used as a reason for postponing decisions where there is a risk of serious or irreversible harm.

Present value is the amount of money that must be invested today to earn compound interest in order to yield enough future value to cover costs at a known period in time.

Real return is the actual return on an investment after removing the effect of inflation.

Repository is nuclear facility where used fuel is placed deep underground.

Reprocessing is the physical and chemical treatment of used nuclear fuel for the purpose of recovery and recycling of uranium, plutonium and fission products.

Retrievability is the ability to remove waste from where it has been placed.

Safety is the protection of individuals, society and the environment, from the harmful or dangerous effects of used nuclear fuel, now and in the future.

> **Passive safety** refers to safety systems that do not rely on continuing human activities or intervention to ensure safety.
>
> **Active safety** refers to safety systems that do rely on continuing human activities or intervention to ensure safety.

Seaborn Panel refers to the Nuclear Fuel Waste Disposal Concept Environmental Assessment Panel, under the Chairmanship of Blair Seaborn, established in 1989 by the Government of Canada under the federal Environmental Assessment and Review Process Guidelines Order to review the safety and acceptability of AECL's concept of geological disposal of nuclear fuel wastes in Canada.

Security is a condition in which a referent entity or process is made and kept safe against harmful acts, events and situations (which are not of a social construction). Activities include threat, vulnerability and consequence assessments, and mitigation activities. Includes both physical and policy considerations.

Sedimentary rock is a type of rock resulting from the consolidation of loose material that has accumulated in layers.

Storage is a method of maintaining used nuclear fuel in a manner that allows access, under controlled conditions, for retrieval or future activities.

Subduction zone is a descending plate of the earth's crust.

Technical method is the technology, technical process or procedure for handling used nuclear fuel. It is one part of a management approach.

Transmutation of used nuclear fuel refers to transforming fission products and particularly the minor actinides into non-radioactive isotopes by exposing them to neutrons or possible other particles.

Used nuclear fuel means the irradiated fuel bundles removed from a commercial or research nuclear fission reactor.

Values as defined by Canadian Policy Research Networks (CPRN), are the ideas that people value greatly. Values run deep. They are the things that we care most deeply about, but may be the hardest to articulate.

Waste is a fuel bundle from a commercial or research nuclear reactor that has served its intended purpose and has been removed from the reactor.

Wet storage is the interim storage of used nuclear fuel in water-filled pools after its removal from the reactor.

APPENDIX 14 / ACRONYMS

ACR	Advanced CANDU Reactor
AECL	Atomic Energy of Canada Limited
AECB	Atomic Energy Control Board
AFN	Assembly of First Nations
ASN	Authorité de Sûreté Nucléaire – Nuclear Safety Commission (France)
BAPE	Bureau d'audiences publiques sur l'environnement – (Public Environmental Hearing Board)
BIER	Biological Effects of Ionizing Radiation
CANDU	CANada Deuterium Uranium
CAP	Congress of Aboriginal Peoples
CEAA	Canadian Environmental Assessment Act (administered by the Canadian Environmental Assessment Agency)
CEO	Chief Executive Officer
CLAB	Centralized Interim Underground Wet Storage Facility (Sweden)
CNS	Canadian Nuclear Society
CNSC	Canadian Nuclear Safety Commission
CoRWM	Committee on Radioactive Waste Management (UK)
CPI	Consumer Price Index
CPRN	Canadian Policy Research Networks
CRC	Cottonwood Research Council
CRL	Chalk River Laboratories
DGR	Deep Geologic Repository
DOE	Department Of Energy (US)
HLW	High Level Waste
HLRWM	High Level Radioactive Waste Management
HQ	Hydro-Québec
HRL	Hard Rock Laboratory
IAEA	International Atomic Energy Agency
ICRP	International Commission on Radiological Protection
JWO	Joint Waste Owners
LLRWM	Low Level Radioactive Waste Management
LWR	Light Water Reactors
MOX	Mixed-Oxide Fuel
MUA	Multi-attribute Utility Analysis
MW	Megawatt
NAFTA	North American Free Trade Agreement
NAGRA	National Co-operative for the Storage of Nuclear Waste (Switzerland)
NBP	New Brunswick Power
NEA	Nuclear Energy Agency
NEB	National Energy Board
NFWA	Nuclear Fuel Waste Act
NPD	Nuclear Power Demonstration
NPP	Nuclear Power Plant

NPRC	Northern Plains Resource Council
NSCA	Nuclear Safety and Control Act
NWMO	Nuclear Waste Management Organization
OECD	Organization for Economic Co-operation and Development
ONFA	Ontario Nuclear Funds Agreement
OPG	Ontario Power Generation Inc.
OPS	Operations
PV	Present Value
PWR	Pressurized Water Reactor
R&D	Research and Development
SLOWPOKE	Safe Low-Power Kritical Experiment
SDR	SLOWPOKE Demonstrator Reactor
SMC	Stillwater Mining Company
SKB	Swedish Nuclear Fuel and Waste Management Company
SPA	Stillwater Protective Association
UF	Used Fuel
UCF	Underground Characterization Facility
UNSCEAR	United Nations Scientific Committee in the Effect of Nuclear Radiation
URL	Underground Research Laboratory

APPENDIX 15 / FIGURES AND TABLES

Figures

Tables

NUCLEAR WASTE MANAGEMENT ORGANIZATION

SOCIÉTÉ DE GESTION DES DÉCHETS NUCLÉAIRES