FINAL GUIDELINES

FOR THE PREPARATION OF AN ENVIRONMENTAL IMPACT STATEMENT

ON

THE NUCLEAR FUEL WASTE MANAGEMENT AND DISPOSAL CONCEPT

Issued by:

The Federal Environmental Assessment Review Panel

March 1992

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EXECUTIVE SUMMARY

This document was prepared by the Environmental Assessment Panel reviewing the Nuclear Fuel Waste Management and Disposal Concept. It contains guidelines for the preparation of an Environmental Impact Statement (EIS), and identifies issues which the Panel has determined should be addressed in the EIS. The EIS will be prepared by the proponent, Atomic Energy of Canada Limited (AECL).

1. Introduction

The EIS should describe in sufficient detail all components of the proposed concept to provide the rationale and the necessity for the concept, now or in the future. It should provide an understanding of why it was chosen from among a number of other possible concepts including those being considered by other countries.

The proponent is encouraged to present the EIS in a clear and comprehensible manner by providing a glossary of technical terms, diagrams and charts, a bibliography of reference sources, appropriate case studies, and scenario analyses. The proponent should not hesitate to include any information that contributes to a fuller understanding of part or all of the concept.

2. The Problem

The EIS should define and explain the overall problem posed by nuclear fuel waste in Canada, and discuss the present magnitude and expected growth of this problem. It should state the need for long-term management of nuclear fuel waste and why this issue must be addressed now. The EIS should specify the risks to the health of humans and to the natural environment. It should also describe the origin and nature of nuclear fuel waste in order to provide a clear understanding of the requirements for its safe management. Current methods of nuclear fuel waste management in Canada should be discussed.

3. The Concept

The EIS should describe the proposed concept in its entirety, and present performance analyses of the concept in quantitative terms wherever possible. The proponent should document the sequence and timing of the events involved in the construction, operation, and decommissioning of a disposal site, and the possible impact on humans, human communities and the natural environment.

The EIS should summarize the history of the formulation and development of the concept, and state the criteria and assumptions used. A discussion of any past decisions taken during this formulation and development should also be included. The EIS should discuss any changes in the concept, or key components of the concept, that have occurred during its development, and state the reasons for these changes. It should outline the reasons for developing a concept based on deep burial of nuclear fuel waste and discuss the implications of the proposed concept for future generations. It should describe the regulatory criteria with which concept implementation, transport of nuclear fuel waste, and concept performance must comply. As well, the EIS should outline plans for the retrieval of nuclear fuel waste under emergency or other circumstances.

4. Alternatives

The EIS should discuss in sufficient detail the ability of possible alternative methods of disposal to address the risks to the health of humans, human communities and the natural environment, and to meet the need for long-term management of nuclear fuel waste. The EIS should also indicate how the proposed concept may compare with alternative methods in terms of possible social impact, risk and cost. As well, the EIS should describe any significant differences between nuclear fuel waste produced in Canada and in other countries and the impact these differences might have on the selection of a disposal concept.

5. The Multiple Barrier System

The EIS should explain the objectives, principles and assumptions involved in the development of the proposed Multiple Barrier System. The concept of a 'barrier' should be fully explained as should each component of the system in physical, chemical, and biological terms. Analyses and assessments of performance of the Multiple Barrier System and its components should be presented in quantitative terms wherever possible.

The EIS should describe the specific functions and quantify possible malfunctions or potential changes in any of the components that could affect the overall performance of the Multiple Barrier System. A description of the components of the proposed Engineered Barriers System and the methods employed for the evaluation of these components should be included.

The EIS should describe and justify the role of the container system in the Engineered Barriers System and compare and contrast it with alternative container systems developed by waste management programs in other countries. The EIS should describe the predicted performance of the container system by identifying all probable modes of container failure.

The EIS should describe the role of the vault in the Multiple Barrier System and examine all aspects of the vault design, construction, operation, sealing and monitoring that affect its functioning as a barrier against contaminants.

The EIS should define and justify the role of the rock mass as part of the Multiple Barrier System as well as explain how a generic model for the rock mass can be established and justified. Criteria for the rejection of a rock mass should also be explained.

The EIS should define and justify the selection of the generic characteristics of the surface environment used in assessing possible environmental impacts of the concept.

The EIS should also address a number of microbiological factors with respect to their potential to affect the integrity of the Multiple Barrier System and the release of potentially harmful chemicals to the surface environment.

6. Performance Assessment of the Proposed Multiple Barrier System

The EIS should discuss in detail, and justify the procedures and approaches used to predict, the long-term performance of the proposed Multiple Barrier System. Particular consideration should be given to risks to the health of humans and the natural environment. A schematic representation of the relationships of models within the entire performance assessment complex and a comparison of this performance assessment with those developed in other countries should also be included.

Modelling procedures to evaluate the short-term and long-term responses of the physical system(s), and the scenarios modelled, should be described according to criteria detailed in the document. Particular care needs to be taken in long-term modelling due to the fact that it transcends the time scale of recorded human experience.

7. Concept Implementation

The EIS should discuss the strategy and methodology for the implementation of the concept.

The proponent should make use of appropriate case studies of the implementation of major projects in Canada that may assist in the understanding of the concept implementation, in particular, an understanding of the social and economic aspects of such implementation.

The EIS should demonstrate a capability for investigating and characterizing actual candidate sites for the safe and acceptable disposal of nuclear fuel waste. This should include an investigation and characterization of social, economic, and cultural conditions of candidate sites. As well, the EIS should discuss the methods that may be used to integrate data from specific sites, and to translate these data into quantities required as input for computational models.

The EIS should discuss options for a siting process for selection of a disposal facility site and transportation routes, such as the use of past and present site selection methods and experiences, should the concept be determined to be safe and acceptable.

The EIS should describe the proposed disposal facility, complete and at various phases of development, and discuss the major activities associated with the development of the disposal facility including site preparation, construction of surface, underground and auxiliary facilities, operation, decommissioning, and site restoration. The EIS should describe the activities associated with the implementation of the various phases of the proposed disposal facility with particular attention given to the phases associated with the storage and handling of nuclear fuel waste. Additionally, the EIS should define and discuss in detail the anticipated labour and resource requirements for the various phases of disposal facility development.

The EIS should describe and discuss in detail possible approaches or options for the transport of nuclear fuel waste from storage facilities to underground emplacement. As well, the EIS should discuss the possible risks associated with the proposed transportation system, how these risks may be distributed along transport routes, and ways that the public may be involved in the selection, development and operation of the transportation system.

The EIS should describe the proposed transport container system, and provide a comparison of this system with alternative container systems for the transport of nuclear fuel waste.

The EIS should describe and discuss in detail possible approaches or options for the overall management of the transportation of nuclear fuel waste from storage to its emplacement in a disposal vault.

The EIS should discuss the mitigative measures that may be required for the protection of the natural environment from the activities associated with the development and operation of the disposal facility, and with the transport of nuclear fuel waste.

The EIS should discuss the measures that are required to protect workers during all activities associated with the development and operation of the disposal facility, and during the transport of nuclear fuel waste.

The EIS should describe and discuss in detail the possible approaches and options for the monitoring of changes in the work place, in human communities, and in the natural environment that may result from all phases of disposal facility development and operation, and from the transport of nuclear fuel waste.

The EIS should discuss possible approaches or options to a planning and response system for emergencies that may arise during all activities of disposal facility development and operation, and during the transport of nuclear fuel waste.

As well, the EIS should provide an estimate of the internal cost of the concept and should address the question of external costs, including those measurable costs that would fall upon municipalities and other jurisdictions.

8. Impacts

The potential social, economic and environmental impacts of the implementation of a disposal facility and of the contents of a disposal vault on humans, human communities, the work site and the natural environment should be described and discussed in detail. This description and discussion should be done clearly, unambiguously and, wherever possible, quantitatively. The proponent should consider the different viewpoints when presenting its EIS, particularly the viewpoints of aboriginal peoples and the viewpoints of other public groups that have a significant potential of being impacted.

The proponent should develop a strategy for the evaluation of possible impacts from concept implementation and from the contents of a disposal vault. The purpose of this strategy is to establish a long-term comprehensive system that will acquire and incorporate new knowledge as it becomes available.

Ethical and moral perspectives, along with various social issues, as evidenced by presentations to the Panel at the scoping meetings, are as important as scientific, technical and economic considerations. The proponent should investigate how relatively narrow and focused considerations of a scientific, technical or economic nature should be viewed in the much broader context of ethical, moral and social considerations.

The proponent should present and describe in detail a long-term comprehensive strategy for the evaluation of possible impacts from concept implementation, the transport of nuclear fuel waste, and from the contents of a disposal vault. This strategy should be fair in process, flexible in its response to new information, and reflect an understanding of the ethics and values of review participants, in particular, those groups that could be most affected by the disposal concept.

The EIS should document and discuss in detail the present state of knowledge about possible impacts of concept implementation and the contents of the disposal vault on humans, human communities, the work site and the natural environment. The proponent should make ample use of appropriate case studies of the impacts, particularly socio-economic impacts, of on-going or completed major projects in Canada.

In addition to the analyses of the results of case studies to enhance the current knowledge base, the EIS should study and model carefully selected scenarios representative of a variety of possible conditions and circumstances to determine possible impacts.

The EIS should describe and distinguish the various sets of baseline conditions that are required for assessment, and the methods and criteria used in the selection of these baseline conditions.

The changes in the human communities and the natural environment (independent of the establishment of the disposal facility) that can be expected, and how these changes may affect baseline conditions, should be discussed.

The EIS should discuss the potential health impacts of radiation, radionuclides and other contaminants on humans and various components of the natural environment in the short term and the long term.

The EIS should also review what is known about the effects of radioactivity on non-human biota. Knowledge about these effects should then be used to evaluate potential short- and long-term impacts on biotic populations and communities, and on ecosystems.

Significant impacts on humans, human communities and the natural environment (geosphere, biosphere, hydrosphere and atmosphere) as a result of disposal facility construction, vault loading, and closure, and the transport of nuclear fuel waste, should be described and quantified. As well, the local and regional significances of these impacts should be identified.

The EIS should present a methodology to assess possible impacts on representative reference communities. Recognition should be given to the integration of competing resource and land use by current human and natural activities in these reference communities, and the possible changes that could occur in this integration due to concept implementation.

Long-term impacts relate primarily to unforeseen events, worse-than-expected conditions, or gradual changes in the natural environment that might cause discharges at unexpected rates of radionuclides and other contaminants from confinement. Conditions under which such discharges to the natural environment might occur, the risks of such occurrences, and the possible impacts, including the accumulation of impacts from other sources on humans and the natural environment, should be described and discussed in detail. The EIS should also discuss the ethical dimensions of disposal vault closure in relation to possible long-term impacts on humans and the natural environment.

Preamble

This document was prepared by the Environmental Assessment Panel reviewing the Nuclear Fuel Waste Management and Disposal Concept. It contains guidelines for the preparation of an Environmental Impact Statement (EIS), and identifies issues which the Panel has determined should be addressed in the EIS. The EIS will be prepared by the proponent, Atomic Energy of Canada Limited (AECL).

The federal Environmental Assessment and Review Process requires that proposed projects that may result in significant adverse environmental effects be referred for public review to an Environmental Assessment Panel appointed by the Minister of the Environment. In September, 1988, AECL submitted for public review its concept for the deep geological burial of nuclear fuel waste in Canada, and subsequently a Panel was appointed in October, 1989.

The Panel was given the mandate to undertake a review of the safety and acceptability of the AECL concept, along with a broad range of nuclear fuel waste management issues. It should be noted that since a concept for the management of nuclear fuel waste is being reviewed, actual site selection will not take place until a disposal concept has been accepted as safe. The Panel will take into consideration the various approaches to the long-term management of nuclear fuel waste, which is presently stored at reactor sites. This will include long-term storage with the capability for continuing intervention in the form of monitoring, retrieval and remedial action, and the transition from storage to permanent disposal. In reviewing AECL's concept, the Panel will become fully aware of the programs of other leading countries in this field, in particular those countries' consideration of different geological media or rock types. The Panel will also become aware of the development of programs for appropriate plans and schedules for siting and construction of nuclear fuel waste management facilities in these countries.

The Panel will also examine criteria by which the safety and acceptability of a concept for long-term waste management and disposal should be evaluated, general criteria for the management of nuclear fuel waste as compared to wastes from other energy and industrial sources, and the impact of recycling or other processes on the volume of nuclear fuel waste.

As well, the Panel will take into consideration the degree to which future generations should be relieved of the burden of looking after nuclear fuel waste, and examine the social, economic and environmental implications of a possible nuclear fuel waste management facility.

The Panel will review the methodology required to characterize sites and the potential availability of sites in Canada. The Panel will also review general criteria for site selection, and advise on a future site selection process in addition to examining, in general terms, the costs and benefits to potential host communities.

In addressing specific issues within its mandate, the Panel will request additional information from sources other than the proponent, including the public, interest groups in their areas of expertise, academic institutions, and government agencies. This information will be part of the public record.

The Panel will receive the EIS submitted by AECL and will distribute it to review participants for comment. If the Panel decides that the EIS is incomplete or inadequate, it will ask for additional information before scheduling public hearings. Once the Panel is satisfied that the EIS has adequately addressed the issues identified in the guidelines, it will announce public hearings. Review participants will have the opportunity to present their views on the AECL concept at the public hearings.

The Panel will consider all of the submissions received during public hearings and will present its conclusions and recommendations in its report to the Ministers of Environment and of Energy, Mines and Resources. The Minister of Energy, Mines and Resources, after discussion with the Minister of Environment, will decide whether the concept proposed by AECL is safe and acceptable, and what further steps must be taken to assure the safe and acceptable management of nuclear fuel waste in Canada.

Discussions and analyses on the scientific, technical, ethical, social, and economic aspects must be considered with the same degree of attention and rigour throughout the EIS. Also, the proponent must present its analyses and assessments of the concept or components of the concept in quantitative terms wherever applicable and appropriate. All sources of information and supporting data used in these analyses and assessments should be identified.

1. INTRODUCTION

The EIS should describe in sufficient detail all components of the concept to provide the rationale and the necessity for the concept now or in the future, and an understanding of why it was chosen from among a number of other possible concepts including those being considered by other countries. Each section within this guidelines document has a specific purpose. Section 2 introduces the problem of nuclear fuel waste, asks for a description of the current nuclear fuel waste management practices and a discussion of risks from the wastes in general and from current waste management practices. Section 3 introduces the concept, asks for a discussion of its development and rationale, and an outline of the underlying criteria and assumptions. As well, a discussion on the potential risks if the concept was implemented is requested. In Section 4, the proponent is asked to describe and compare alternatives to the concept. Section 5 requests a detailed discussion of the Multiple Barrier System, and its components, namely, the nuclear fuel waste itself, the disposal container system, the disposal vault system, the rock mass, and the surface environment. In Section 6, the proponent is asked to describe and discuss the procedures that will be used in assessing how the Multiple Barrier System will perform. Section 7 requests a description of concept implementation including site characterization, the disposal facility, the transportation system, environmental and occupational protection measures, monitoring procedures, and emergency planning measures.

In the final section, Section 8, the proponent is asked to describe and discuss in detail the possible impacts on humans, human communities, the work site and the natural environment resulting from concept implementation, and from the contents of a disposal vault. Many of these impacts may at present be largely unknown or incompletely defined given the conceptual nature of this review. In response to these limitations and unknowns, the proponent is asked to develop a long-term comprehensive strategy that will establish what is currently known about possible impacts, incorporate new knowledge as it becomes available to better understand possible impacts, allow for changes in the design and implementation of the concept, and, if possible, reduce or eliminate adverse impacts. Ethical and moral perspectives, along with various social issues, are considered to be as important as scientific, technical and economic considerations to assure safe and acceptable management of nuclear fuel waste. The proponent should include in this strategy an investigation of how relatively narrow and focused considerations of a scientific, technical and economic nature should be viewed in the much broader context of ethical, moral and social considerations.

A glossary of definitions of some terms used in this guidelines document is included in an appendix.

The short term is understood to be the time period of planned human activities at a disposal facility site. It includes the period of the site characterization and preparation, construction, the loading and closure phases, the site decommissioning phase, and a post-closure monitoring phase. The long term covers the time period after disposal vault closure and decommissioning of the disposal facility.

Various public groups in Canada, such as residents of northern communities, aboriginal peoples, people living near possible transport corridors, etc. may have different viewpoints on many aspects of the concept. The proponent should consider these different viewpoints when presenting its EIS, particularly the viewpoints of public groups that have a greater potential of being impacted as a result of concept implementation.

The proponent is encouraged to present its EIS in the clearest terms possible, and to use language, where possible, that can be readily understood by the public. However, where the complexity of issues addressed requires the use of technical or uncommon language, and words or phrases which may otherwise be interpreted in various ways, a glossary clearly defining terms should be included. As well, the use of diagrams and charts is recommended wherever possible, as is the inclusion of a bibliography of the references used to prepare the EIS. In order to achieve a clearer understanding of the concept, in particular the socio-economic aspects, the proponent is encouraged to make use of appropriate analogs, natural and otherwise, appropriate case studies of actual projects, and scenario analyses.

The EIS should begin with a summary of the document and its findings that is easily understood by the general public. It should provide the reader with a concise idea of the contents of the EIS and should focus on items of specific interest. The summary should be prepared for wide distribution as a document separate from the EIS. The EIS summary and main document should be available in both English and French. Technical documents should be provided in the appropriate working language.

The proponent should address the items and requests identified in these guidelines, but should not hesitate to include any information in the EIS that may contribute to a fuller understanding of part or all of the concept. Both positive and negative effects of the concept should be included. The EIS should identify not only aspects of the concept that are well understood, but also aspects for which at present only a limited understanding exists. The proponent is also requested to supply, within the EIS, additional background information and its opinion on various matters that have been determined to be important in the review of the safety and acceptability of the concept.

2. NUCLEAR FUEL WASTE - THE PROBLEM

The EIS should define and explain the overall problem posed by nuclear fuel waste in Canada, and discuss the present magnitude and expected growth of this problem. The EIS should discuss the ethical and moral framework in which the problem posed by nuclear fuel waste should be evaluated, state the need for long-term management of nuclear fuel waste and discuss why this issue must be addressed now. The EIS should specify the risks to the health of humans and to the natural environment. The EIS should also describe the origin and nature of nuclear fuel waste in order to provide a clear understanding of the requirements for its safe management. Current methods of nuclear fuel waste management in Canada should be discussed.

2.1 Risks to the Health of Humans and to the Natural Environment

The EIS should discuss and provide background information about the risks to the health of humans and human communities, and to the natural environment that are associated with nuclear fuel waste. The sources used to obtain this information should be identified. This discussion should include, but not be limited to, the following:

- definitions of health, including community and social dimensions;
- definition of risk;
- analysis of the viewpoints of various public groups, including aboriginal peoples, on risks to the health of humans and to the natural environment;
- processes and mechanisms through which radionuclides (atoms which release radiation) and other contaminants may directly and indirectly impact on humans and various organisms in the natural environment;
- explanation of effects of ionizing radiation on humans and the natural environment, including probability of exposure and the quantification of risk;
- current and proposed health regulations pertaining to ionizing radiation, past changes in these regulations, and reasons for these changes;
- methodologies used in risk assessment and in health assessment, their validity including a discussion of

underlying assumptions, and the theoretical justification for the rationale behind these methodologies;

- theoretical justification for the manner in which probability and magnitude of risk are calculated.

2.2 Nature of Nuclear Fuel Waste

The EIS should clearly explain the nature and magnitude of the present nuclear fuel waste management problem, describing the origin of nuclear fuel waste and other materials intended for disposal and those characteristics that are critical in the evaluation of the disposal concept.

The EIS should discuss the types, sources, quantities and locations of nuclear fuel waste in storage at the present time, and projected at various times in the future. The nature of any uncertainties in these future projections, and the reasons for these uncertainties should also be discussed. The EIS should also discuss the various circumstances which could determine types, sources, quantities and locations of nuclear fuel waste including i) the present rate of electrical generation by nuclear power, ii) a moratorium on nuclear power plant construction, iii) the implementation of reprocessing, iv) the expansion of electrical generation by nuclear power, and v) the possible changes in nuclear technology.

The discussion of the nature of nuclear fuel waste should include, but not be limited to, the following:

- the physical and chemical characteristics of nuclear fuel waste for all relevant time scales, including lists of prominent radionuclides with statements of the probable chemical form of each radionuclide under expected surrounding conditions;

- the nature of the physical and chemical changes that occur in the nuclear fuel while in the reactor, after removal from the reactor, and while in storage or transportation;

- the short-term and long-term variations in the characteristics of the components of nuclear fuel waste including heat, radiation intensity, radiation products and toxicity;

- the possible changes in the nature and characteristics of nuclear fuel waste due to changes in nuclear power technology or in energy policies.

2.3 Current Nuclear Fuel Waste Management in Canada

The EIS should describe current nuclear fuel waste management practices in Canada, the objectives of these practices, and their ability to meet these objectives now and in the future. The EIS should also discuss the environmental and ethical dimensions of these practices.

Past performance of the nuclear industry in managing nuclear fuel waste should be documented. Any containment failures that have occurred during storage at, and transport between, nuclear facilities, and any subsequent impacts on humans, human communities, the work site and the natural environment, should be described. The history of the experience with containment designs and construction materials should be outlined. The EIS should compare current nuclear waste management practices in Canada with those of other countries.

The EIS should discuss the history of nuclear fuel waste management since the beginning of nuclear power generation, including preference for disposal versus storage, and any changes in this understanding. In this discussion, the views of public groups, in particular people living near current storage facilities and residents of more northerly communities, should be included.

2.4 Risks: Current Nuclear Fuel Waste Management

The EIS should discuss the risks to the health of humans and human communities, and to the natural environment, that are associated with the current management of nuclear fuel waste. The sources used to obtain this information should be identified. This discussion should incorporate issues discussed in Section 2.1 where appropriate and include, but not be limited to, the following:

- consideration of risk on the basis of total population and the individual;

- consideration of risk due to ionizing radiation on the basis of physical and genetic effects;

- risk criteria which relate to human health and environmental protection, and assumptions taken in development of these criteria;

- distinction between risks due to the current management of nuclear fuel waste and risks due to background radiation;

- risks resulting from social processes (e.g. accidental human intrusion or criminal intervention), geological processes (e.g. earthquakes, meteorite impacts, rupture of bedrock due to post-glacial isostatic rebound), microbiological processes, and changes in the surface environment (e.g. short-term climate change);

- risks from possible accidents that may result in radiation exposure or the release of other contaminants (e.g. an unexpected major leakage).

2.5 Security of Long-term Management of Nuclear Fuel Waste

The EIS should elaborate on the provisions that currently exist to assure the security of long-term management of nuclear fuel waste in Canada and internationally, including provisions to safeguard against loss of knowledge or nuclear expertise. Examination of the history of the performance of these provisions, and their ability to accommodate the requirements of future long-term management options should be included.

3. THE AECL CONCEPT

The EIS should thoroughly describe the concept in its entirety, and present analyses and assessments of performance of the concept or components of the concept in quantitative terms wherever possible. Sources of all data used in analyses and assessments should be identified. Due to the complexity and recent development of the technology involved, the lack of experience in its implementation, and the conceptual nature of information concerning a potential site, it is important that this description of the concept is presented clearly. A careful documentation must be provided of the sequence and timing of all events that would occur if a disposal facility was sited, constructed, operated and decommissioned, and a transportation system was implemented. The linkages of these events to all possible impacts on humans, human communities, the work site and the natural environment is an essential requirement. Measures that could be taken to mitigate possible impacts should also be described. As well, the possible impacts, at various time intervals, on humans and the natural environment, from the contents of a breached disposal vault, and the likelihood of such breaching, must be thoroughly described and discussed.

During this description and discussion of the concept, the following important issues should be addressed wherever appropriate:

- the assumptions and rationale underlying all decisions that will assist in the understanding and evaluation of the concept;

- regulatory criteria (particularly for health and risk), their adequacy and their feasibility of being met, and areas where further development of criteria is required and where no criteria presently exist;

- identification of what is uncertain or unknown, and how these uncertainties, in particular irreducible uncertainties, are treated;

- identification of gaps in significant knowledge;

- important areas of knowledge where differing opinions within the physical scientific community remain unreconciled;

- demonstrated ability of involved experts to integrate new data;

- possible areas where future research results could cause a re-evaluation of the concept;

- the ranking of various phenomena and processes which may affect the performance of a future disposal facility in terms of overall risk to humans and the natural environment;

- sources of data and information used;

- the use and justification of site-specific data, and its representativeness of human communities and of the natural environment in candidate site environments;

- the flexibility of the concept or key components of the concept to accommodate possible unanticipated circumstances, (e.g. changes in i) nuclear fuel waste generation rates, ii) technology, iii) selection of or preference for host media, iv) the understanding of environmental hazards and risks, v) regulatory criteria, vi) social priorities and values, and vii) government policies), and the implication of these possible circumstances for concept design and implementation;

- security measures;

- quality control and quality assurance of all aspects of the concept.

The EIS should also address various possible scenarios with respect to the amount of nuclear fuel waste that must be accommodated, including:

- no growth or reduction in nuclear power production;

- the shutdown of existing nuclear power facilities;

- the implementation of reprocessing;

- major growth in nuclear power production, for example to replace fossil fuel power production;

- possible changes in nuclear technology.

3.1 Development of the Concept

The EIS should summarize the history of the formulation and development of the concept, and state the criteria and assumptions used. A discussion of any past decisions taken during this formulation and development should also be included. The EIS should discuss any changes in the concept, or key components of the concept, that have occurred during its development, and state the reasons for these changes.

In describing the history of the development of the concept, the

EIS should examine, but not be limited by, the following:

- the sequence of events and the rationale that has resulted in the proposed nuclear fuel waste management program in Canada;
- the roles of key parties involved in decision-making;
- public consultation in the development of the nuclear fuel waste management program;
- an indication of the responsiveness of the proponent to suggestions about concept development from outside agencies and individuals;
- differences between the present disposal concept and the concept originally described in the mandate given the proponent;
- the current status of the program, and a summary and schedule of research planned, in progress, or completed, including the identification of the status of any planned or ongoing research which may not be completed before the public hearing phase of this review.

3.11 Rationale for Deep Burial of Nuclear Fuel Waste

The EIS should outline the reasons for developing a concept based on deep burial (geologic disposal) of nuclear fuel waste. The implications of the concept for future generations and the present society's responsibilities to those generations should be discussed. This discussion should take into account how various public groups, particularly aboriginal peoples, within the present society view their responsibilities to future generations. The EIS should also discuss the environmental and ethical dimensions of this concept of managing nuclear fuel waste.

3.12 Criteria and Assumptions

The EIS should outline the regulatory criteria with which concept implementation, the transport of nuclear fuel waste, and concept performance must comply. As well, the EIS should discuss the criteria the proponent has established and the assumptions the proponent has used during the development of its concept. This should include, but not be limited to, the following:

- definitions of safety and acceptability;
- criteria and assumptions for safety, and technical and social

acceptability;

- criteria used for a decision to close and decommission an underground disposal vault;

- criteria for and assumptions about the responsibility to present and future generations, both those at the site where nuclear fuel waste is generated and at a possible disposal site;

- the ability of the concept to meet the requirements of regulatory criteria as well as the proponent's own criteria for safety, and for technical and social acceptability.

3.2 Potential Risks: Nuclear Fuel Waste Management Concept

The EIS should discuss and, where possible, quantify the risks to the health of humans and human communities, and to the work site and the natural environment, that are associated with the concept for both the management and the transport of nuclear fuel waste. The EIS should also discuss how these risks will differ or be redistributed from those associated with the current management of nuclear fuel waste. The sources used to obtain this information should be identified. This discussion should incorporate issues discussed in Section 2.1 where appropriate, and take into account how various public groups within present society, particularly aboriginal peoples, may view risk. This discussion should include, but not be limited to, the following:

- risk on the basis of total population and the individual;

- risk due to ionizing radiation on the basis of physical and genetic effects;

- factors that would be involved in considering the redistribution of risk (i.e. from populations living near the site of nuclear fuel waste generation to populations living near a potential disposal site, and along potential transportation routes);

- risk criteria which relate to human health and environmental protection, the assumptions taken in development of these criteria, and how these criteria differ from those associated with the current management of nuclear fuel waste;

- distinction between risks due to the concept for the management of nuclear fuel waste and risks due to background radiation;

- risks resulting from social processes (e.g. accidental human intrusion and criminal intervention, changes in land use, etc.), geological processes (e.g. earthquakes, meteorite impacts, rupture of bedrock due to post-glacial isostatic rebound), microbiological processes, and changes in the surface environment (e.g. short-term climate change);

- risks resulting from possible accidents that may result in radiation exposure or the release of other contaminants (e.g. an unexpected major leakage);

- a definition of safety in relation to the concept, and an outline of what would constitute adequate proof of safety.

The EIS should discuss the capability of the concept to address the risks to the health of humans and human communities, and to the work site and the natural environment, and to meet the need for the long-term management of nuclear fuel waste. The discussion should include a comparison of the range and distribution of risks incurred by an extension of current nuclear fuel waste management practices compared to those which would be incurred by the concept.

3.3 Retrieval of Buried Nuclear Fuel Waste

The EIS should outline plans and procedures which would be required for the retrieval of nuclear fuel waste from a sealed and decommissioned disposal vault under emergency or other circumstances. This should include estimates of the cost of such an operation, and a consideration of how retrieval can be facilitated in the design of the concept. It should also include an examination of whether and if so to what extent provisions for retrieval would affect the safety of the concept.

4. ALTERNATIVES TO THE CONCEPT

The EIS should discuss the capability of possible alternatives to the concept to address the risks to the health of humans and human communities, and to the work site and the natural environment, and to meet the need for long-term management of nuclear fuel waste. Each alternative should be described, where possible, at a level of detail sufficient to permit a meaningful comparison with the concept. The EIS should also indicate how the concept may compare in terms of possible social impact, risk and cost with other possible alternatives. This discussion should incorporate issues raised in Sections 2.1, 3.12, and 3.2 where appropriate and include, but not be limited to, the following:

- a review of current and proposed practices of other countries for the long-term management of nuclear fuel waste and other high-level radioactive waste;
- the implication of a number of separate or dispersed disposal facilities instead of one consolidated facility;
- a consideration of a disposal facility at a site or sites of nuclear power generation;
- a consideration of alternative media for geologic disposal of nuclear fuel waste in Canada;
- long-term above ground and underground storage;
- a consideration of storage at a centralized underground waste management facility, and the possible transition at a future time to permanent geological burial;
- a consideration of the transmutation of nuclear fuel waste.

The EIS should describe any significant differences between nuclear fuel waste produced in Canada and in other countries (e.g. waste produced from enriched versus natural fuels, reprocessed versus non-reprocessed waste), and explain how these differences might influence the selection of a disposal concept.

5. ISOLATION OF NUCLEAR FUEL WASTE - THE MULTIPLE BARRIER SYSTEM

The EIS should explain the objectives, principles and assumptions involved in the development of the proposed Multiple Barrier System to isolate nuclear fuel waste. Analyses and assessments of performance of the Multiple Barrier System and its components should be presented in quantitative terms wherever applicable and appropriate. In this explanation, the term barrier and the relationships between barriers should be defined. Examples of barriers from the entire system should be given. The EIS should also describe each component of the Multiple Barrier System in physical, chemical and biological terms, its specific functions and, in particular, the linkages among the various components. The EIS should also describe and quantify possible malfunctions of one or more of the barriers, or potential changes in the disposal vault environment that could affect the overall performance of the Multiple Barrier System.

The EIS should document and discuss in detail procedures for evaluating the performance of the components and of the total barrier system for the anticipated time required for nuclear fuel waste isolation. This discussion should identify the critical stages and expected times leading to the ultimate breaching of each component and of the whole system. Uncertainties in these expected times should be discussed, and critical stages leading to the ultimate breaching of each component and of the entire system should be identified. These critical stages should be displayed graphically on time charts.

The EIS should also demonstrate that adequate long-term performance criteria have been developed for each of the components of the system, and for the system as a whole. A comparison with regulatory criteria adopted for nuclear fuel waste management programs in other countries with significant nuclear fuel waste should also be provided.

Since the ultimate objective is to prevent or delay the dispersal of radionuclides and other contaminants into the environment, the EIS should discuss the possible migration of radionuclides and other contaminants at all stages and through all barriers. In this discussion, the EIS should consider, but not be limited to, the effects of pH, Eh, temperature, rock composition, hydraulic flow rate, microbiota and other factors on the migration through various barriers.

5.1 The Engineered Barriers System

The EIS should describe the components of the proposed Engineered Barriers System and the methods employed for the evaluation of these components. It should describe the characteristics of the vault environment and the processes that govern the migration of radionuclides and other contaminants within that environment. It should also describe and evaluate the changes that may occur in these characteristics and processes over time. Consideration should be given to the time period of planned human activity at a disposal facility, and the time period following the sealing of the disposal vault and decommissioning. The EIS should address the possibility of components of the nuclear fuel waste attaining critical mass.

5.11 Nuclear Fuel Waste

The EIS should describe the role of the nuclear fuel waste itself and of the fuel bundle, as part of the Multiple Barrier System. The effectiveness of the nuclear fuel waste as a barrier should be evaluated, taking into account its chemical and physical stability, its potential for biological mobilization, and its susceptibility to damage from its own radiation and heat. The basis for the decision concerning the form in which the nuclear fuel waste is to be placed in the container should be explained. This decision should be compared and contrasted with alternatives adopted by waste management systems in other countries.

The EIS should discuss the hazardous components and characteristics of the nuclear fuel waste, in particular the important radionuclides and the heat production as a function of time. This discussion should include, but not be limited to, the following:

- identification and ranking of the radionuclides and other hazardous components that may be associated with potential health risks to humans and risks to the natural environment;

- description of the relevant chemical and physical properties of these radionuclides and other hazardous components, including their dynamic change over time.

The effect of heat and radiation on the physical and chemical integrity of nuclear fuel waste should be discussed, particularly with respect to the rates of ultimate release of specific radionuclides. The EIS should describe the methods used to estimate radionuclide release and consider the following:

- rates and processes of the dissolution of nuclear fuel waste;

- the development of regions of induced strain and of voids;

- the effect of radiation-induced changes on leaching rates of structural components and of critical nuclides;

- the potential for the generation of gases by chemical, nuclear and biological processes, and the consequences of the presence of these gases;

- the potential for other biological and microbiological interactions with nuclear fuel waste;

- the possible dissolution mechanisms of nuclear fuel waste including biologically mediated mechanisms and selective leaching.

The EIS should provide details and specifications of the pre-disposal storage of nuclear fuel waste, including location, storage time and the effect of storage and handling on the integrity of nuclear fuel waste, and on its effectiveness to perform as a barrier.

5.12 The Container System

The EIS should describe the role of the container system in the Engineered Barriers System. The components of the proposed container system that would function as a barrier against the migration of radionuclides and other contaminants should be examined. The preferred container system should be compared to alternative container system concepts developed by nuclear waste management programs in Canada and in other countries.

The EIS should describe and justify the design and manufacturing criteria applied to the container system. This discussion should include, but not be limited to, the following:

- the selection of container design including provisions for change and future improvements;

- the selection of structural materials for the container system including present and future availability of materials, provisions for change, and justification for selection of materials including materials with no known natural analogs;

- the selection of filling materials for inside the container, and the justification for their selection;

- the suitability of the designed container system for the selected method of handling and emplacement;

- the inspection and quality control procedures for all stages from fabrication to emplacement under full-scale operational conditions.

The EIS should describe and justify the proposed method for the loading and sealing of the container.

The EIS should describe and discuss in detail the circumstances and mechanisms leading to all possible causes of container failure, in particular container breaching either by corrosion mechanisms operating in the vault environment or by the crushing action of all possible rock pressures. Results from the investigations of these circumstances and mechanisms should be presented as quantitatively as possible. Measures to delay or reduce the possibility of breaching, and to minimize its effects should also be described.

The EIS should describe the predicted performance of the container system by identifying all probable modes of (total and local) failure of the container, taking into account the thermomechanical history from fabrication through emplacement. The description should include, but not be limited to, the following:

- a definition of container failure, and a discussion of the probabilities and consequences of single or multiple container failure;

- a quantitative description of the results of tests performed on actual full-size or scale models of the container system, and on the materials used in the manufacture of the container;

- a description of possible models for container failure, a discussion of the extent to which such models have successfully predicted failure in past experiments, and how relevant these experiments were to anticipated vault conditions;

- a discussion of the mechanisms of weakening of the material of the container system including, but not limited to, chemically reducing conditions, groundwaters, gases, and threats imposed by microbially-induced corrosion;

- a discussion of the environment in which the container is emplaced with respect to its possible influence on corrosion and other modes of failure;

- the validity of long-term data extrapolation for time-dependent container degradation mechanisms;

- the application of possible natural and other analogs to the container system and its components.

The EIS should describe methods to be used for monitoring the integrity and performance of the containers under vault conditions including:

- a description of monitoring methods to assess performance and to anticipate early failure, and of strategies if early monitoring indicates failure;

- a statement of the criteria for tolerable deviations from predicted behaviour, and the response plan should deviations exceed tolerable limits;

- a consideration of the effects of radiation and radiolysis on corrosion and embrittlement of a container.

5.13 The Disposal Vault System

The EIS should describe the role of the vault in the Multiple Barrier System. It should examine the entire proposed vault system and all aspects of the vault design, construction, operation, sealing and monitoring that may affect its functioning as a barrier against the migration of radionuclides and other contaminants. The EIS should describe and discuss in detail the effects of the anticipated flow of water through all components of the sealed vault, and along the boundaries of these components. The EIS should also make use of analogs (e.g. deep large excavations, natural caves, etc.) in appropriate rock types to assess the performance of an unsealed vault.

The EIS should discuss how the preferred vault system compares with alternative vault system concepts, as well as those vault systems developed by nuclear waste management programs in other countries.

The EIS should describe the criteria and procedures to be used in the design, construction and operation of the vault. This description should include, but not be limited to, the following:

- the intended function of the vault within the Multiple Barrier System;

- the criteria for choosing excavation technology;

- the justification for the choice of excavation technology;

- the criteria used in the design of the vault, including the choice of shape, dimension and appropriate depth;

- an evaluation of in-room emplacement of containers versus borehole emplacement, with reference to vault construction, overall stability and operation;

- the criteria used in determining the shape and dimensions of the borehole into which the container is placed;

- an evaluation of the risk of instability of the underground openings both locally and globally, including responses to static, thermal and seismic loads;

- an evaluation of fracturing of the rock mass induced by excavation process, and of its impact on the functioning of the rock mass barrier;

- a discussion of criteria for abandonment or rejection of a vault or sections of a vault in which the rock or fracture characteristics are found to be different from those expected;

- a demonstration of the capability to characterize in-situ stresses and estimate elastic strain energy at the appropriate depths in a rock mass, and their potential short-term and long-term consequences;

- an evaluation of the thermal effects of the vault and the nuclear fuel waste on geomechanical properties and processes;

- a discussion of earthquake-resistant design and of increased earthquake activity due to glaciation and deglaciation.

The EIS should describe the potential for, and consequences of, unplanned events during the loading of containers and monitoring stages. This should include, but not be limited to, the following:

- a discussion and evaluation of the methods and hazards of handling the nuclear fuel waste at the various stages;

- a description and evaluation of the container emplacement method and technology, and the quality assurance and control procedures to be used during emplacement;

- an outline of the procedures and standards for the training of staff and the operation of equipment;

- a description and discussion of the methodology to retrieve, decontaminate, and repair damaged containers during all phases of vault operation;

- a description of procedures for handling contaminated materials and equipment;

- a demonstration of the availability of appropriate instrumentation and monitoring techniques for the assessment of deviations from predicted thermal, geomechanical and hydraulic behaviour;

- a description of the contingency plans to take advantage of situations which are more favourable than predicted, and the capability to manage and correct all situations where unfavourable departures from predicted performance are encountered, including retrievability of nuclear fuel waste, if necessary.

The EIS should describe the vault sealing program including the following:

- the criteria to be used in making the decision to seal the vault, including an assessment of acceptable differences between the forecast and the observed performance of the vault;

- the criteria for the selection of the sealing materials (buffer, backfill and grout) over other materials considered;

- the physical and chemical characteristics of the sealing materials;

- the sources and availability of sealing materials with particular attention given to the buffer material, and the methods used to extract or manufacture the sealing materials;

- the specifications, with permissible variability, of the sealing materials, with particular attention given to the buffer material;

- the transportation, emplacement and compaction methods, and the equipment used;

- the quality control of the production and application of sealing materials, including methods of evaluation and criteria for selection and rejection, and the data or experience upon which these criteria are based;

- the functions of the various sealing materials (e.g. as radiological barriers, or to restrict of groundwater flow);

- the nature of the contacts between the sealing materials and the rock mass, and the sealing materials and the containers, the impacts of gaps due to consolidation, shrinkage, and ineffective emplacement at these contacts, and the remedial measures planned;

- the expected long-term performance and integrity of the sealed vault, particularly under conditions of elevated temperature, and full or partial groundwater saturation, and the uncertainties involved;

- the effects of biofouling of the vault, and the sealing materials.

5.2 Rock Mass Barrier

The EIS should define and justify the role of the rock mass as part of the Multiple Barrier System.

The EIS should explain how a generic model for the rock mass can be established and justified. It should explain how field evidence and tests from actual sites can be used to determine generic parameters and characteristics of the rock mass and the associated groundwater flow system. The discussion of those properties of the rock mass and the groundwater flow system that could affect the migration of radionuclides and other contaminants should include, but not be limited to, the following:

- procedures for obtaining a representative description of the important generic geological, hydrogeological, geochemical, biological, thermal, and geomechanical properties and the variations of these properties in space and time (including ranges of values and their uncertainties);

- identification and characterization (including ranges of parameters and uncertainties) of variations (i.e. heterogeneities and discontinuities) in the rock mass and groundwater flow system (such as fracture systems) that will affect the transport of radionuclides and other contaminants;

- relevant physical, chemical, biological and biochemical processes in the rock mass and groundwater flow systems that may impede or enhance the transport of radionuclides and other contaminants, and the coupling between these processes;

- factors that determine the transport of radionuclides and other contaminants from the vault into the rock mass, and from the rock mass and the groundwater flow system into the surface environment;

- ranges of rates and volumes of fluid flow and transport of radionuclides and other contaminants through the rock mass to be expected under present and future conditions (including the associated uncertainties);

- short-term or transient changes in the processes and properties of the rock mass and the groundwater system that may be expected due to the establishment of the disposal vault, including the effect of the biological and thermal changes due to the construction and loading of the vault;

- long-term changes that may affect the rock mass or the groundwater system, for example global climate change, post-glacial isostatic rebound, or renewed glaciation;

- potential changes in the relevant properties and processes in the rock mass due to stress changes, possible geologic events such as earthquakes or meteorite impact effects at the disposal vault depths considered;

- procedures for and limitations of seismic risk assessment (e.g. seismic monitoring, geologic evidence for faulting and earthquakes).

Criteria for the rejection of a rock mass on the basis of its mineralogical, hydraulic, physical, chemical or biological properties, as well as on the basis of assessment of seismic risk, should be stated.

The proponent should also discuss the suitability of alternative geologic media or rock types to perform as rock mass barriers at a level of detail sufficient to permit a meaningful comparison.

5.3 Surface Environment

The EIS should define and justify the selection of the generic characteristics of the surface environment used in assessing possible environmental impacts of the concept. The description of the generic surface environment should clearly indicate: i) which processes, components and pathways are important and why; ii) the ranges of parameters used and how they were selected; and iii) any simplifying assumptions used.

The description of the generic surface environment should include, but not be limited to, the following:

- the key physical, chemical and biological processes that control the movement and concentration of radionuclides and other contaminants in the surface environment;

- the key linkages among the physical, chemical and biochemical processes in the rock mass and in the surface environment;

- the critical pathways and net transport of radionuclides and other contaminants, including through the food chain to plants and animals;

- how short-term or transient changes in processes and properties of the surface environment are dealt with (e.g. changes caused by excavation and loading of the vault, near-term regional or global climate change);

- how long-term changes are dealt with (e.g. possible global change, renewed glaciation, changes in hydraulic gradient due to movements of the earth's crust).

5.4 Microbiological Issues

The EIS should address the following microbiological factors with respect to their potential to affect the integrity of the Multiple Barrier System and the release of potentially harmful substances to the surface environment:

- the present state of knowledge of microbes at depth;

- the origin of microbiological activities that are likely or possible at any stage during nuclear fuel waste storage, preparation, transport, emplacement, or in the vault and rock mass system, and the relative importance of indigenous or introduced organisms;

- the most important sources of nutrients that may be found at any stage of the disposal concept, including those in the rock mass at the proposed vault depth, in the groundwater under expected conditions, and introduced by vault construction, loading and sealing;

- the potential rate (ranges and uncertainties) of microbially-induced corrosion of the disposal container, including the influence of thermal loading, saline groundwater, radiolysis and gas emanations;

- the possibilities and likelihood of enhanced microbial mutation or evolution resulting from higher than normal background radiation levels, and the potential effect of such changes on radionuclide or chemical transport and release;

- the potential for intrinsic microbial activities at any stage from reactor to emplacement, and in the vault or the rock mass barrier, to affect the formation of radiocolloids which might influence the adsorption or movement of radionuclides and other contaminants;

- the nature and rates of microbially mediated processes which may result in the release of radionuclides and other contaminants from a disintegrating vault, the mechanisms by which these contaminants may be modified (e.g. through methylation), the forms in which the modified contaminants may reach the surface environment, and the various possible impacts on humans and the natural environment which may result.

6. PERFORMANCE ASSESSMENT OF THE PROPOSED MULTIPLE BARRIER SYSTEM

The EIS should discuss in detail and justify the procedures and approaches used to predict the long-term performance of the proposed Multiple Barrier System. In this discussion, consideration should be given to risks to the health of humans and to the natural environment, and to specific issues raised in Sections 2.1 and 3.2.

Description of and justification for the various procedures and approaches taken (i.e. mathematical modelling and simulation, analogs, etc.) in assessing the performance of the Multiple Barrier System, and how they are used and integrated, should be included in the discussion. The extent to which these procedures and approaches are flexible enough to accommodate future development and refinements should be examined. A clear statement of the objectives and limitations of the procedures and approaches should also be given.

A schematic representation of the relationships and linkages of models within the entire performance assessment complex should also be included in the EIS.

The procedures chosen for the performance assessment of the proposed Multiple Barrier System should be compared with the alternative performance assessment procedures developed by nuclear fuel waste programs in other countries.

Throughout this section, the short term is defined as the time period of planned human activities at the site, and the long term is defined as the time period beyond decommissioning.

6.1 Selection and Development of Methods for Multiple Barrier System Performance Assessment

The EIS should discuss the selection and development of the mathematical models and other methods used in the performance assessment of the generic Multiple Barrier System. The discussion of model structure should be organized, as far as possible, according to physical systems, processes and mechanisms, and to space and time scales. Assumptions and limitations of the models should be clearly identified.

6.11 Model Components, Systems, Processes, and Mechanisms

The discussion of model components should cover, but not be limited to, those components representing:

- the container system;
- the vault system;
- the rock mass system in the near field (in the order of vault dimensions or size);
- the rock mass system in the far field (extending to natural hydrogeologic boundaries);
- the surface natural environment.

For each component, the physical, chemical and biological principles underlying the model, the relevant space and time scales, the choice of the dimensions of the model, as well as the interfacing with other components should be explained. The choice of solution method, and the justification for this choice, should also be discussed.

The discussion of processes and mechanisms should include, but need not be limited to, the following:

- groundwater flow;
- gas flow;
- heat flow;
- chemical, radiological, biological, and microbiological transformations of and interactions among all active constituents, both mobile and immobile;
- transport of all mobile constituents in their various phases by advection (or dissolved constituents carried in groundwater), dispersion, diffusion, colloidal migration, or other transport processes;
- stresses and deformations in the rock mass;
- the coupling among physical, hydrogeological, chemical, biochemical, and geomechanical processes and mechanisms.

6.12 Assumptions and Limitations

The assumptions made in the model development and the resulting limitations inherent in the models should be discussed. The discussion should include, but not be limited to, the following:

- assumptions made concerning any of the processes and mechanisms, the justification for making the assumptions, and the model limitations and other consequences resulting from the assumptions made;
- any uncertainties in the model output resulting from assumptions made in model development;
- the adequacy of the processes and mechanisms selected for representing the long-term scale;
- the ability of the models to incorporate additional processes, mechanisms, and boundary conditions;
- the representation of fracture systems in the rock mass, the associated groundwater flow systems, and the channelling of groundwater flow within the fracture systems;
- the capability of the various models to accommodate changes in time and space of the external conditions, the system geometry, or other changes;
- implications with respect to the performance assessment of the Multiple Barrier System arising out of the structural limitations of the models.

The EIS should also discuss:

- the implications of conceptual and numerical simplifications made for computational convenience;
- the adequacy of state-of-the-art computing equipment to perform full-scale three-dimensional simulations under conditions of extensive coupling of processes and mechanisms;
- the additional computing equipment required for reasonable utilization of available models.

6.2 Determination of Parameters

The EIS should define all parameters and categories of data used in the generic mathematical models. As well, the EIS should discuss the methods used for determining these parameters and categories of data, and how they are used in the models. The discussion should include, but not be limited to, the following:

- parameter and data requirements for the models;
- the parameter ranges chosen;
- a definition of generic data used in generic models;
- parameter identifiability, stability, and uniqueness;
- criteria used for the selection of parameter ranges, and the justification for the selection;
- the adequacy of the chosen ranges of the parameters over time, particularly the long-term scale;
- the method chosen for translating results of hydrologic tests into model input parameters;
- the method chosen to relate stress changes in the rock mass to changes in the hydraulic parameters;
- the method chosen to translate fracture or channel hydraulic parameters into bulk hydraulic parameters;
- the method chosen to translate results from the groundwater flow model into groundwater velocities for transport modelling;
- the time-dependence of all parameters in the short term (e.g. due to seasonal variations), and the long term (e.g. due to global warming or glaciation);
- uncertainties in the ranges of the parameters used, as well as uncertainties in the variations of these parameters over time;
- the approach chosen to represent and quantify parameter and data uncertainty and parameter errors over the required time scale;
- the use and validity of parametric probability functions, the statistical interdependence of parameters or their correlation (i.e. auto-correlation and cross-correlation), particularly over the long-term scale;
- the desirability of reducing parameter and data uncertainty by collecting additional data, and the cost-benefit relationship of reducing uncertainty in this way;
- the uncertainty that is unquantifiable.

6.3 Model Validation

The EIS should discuss the procedures chosen to validate the models applied in the performance assessment of the Multiple Barrier System. The discussion should include, but not be limited to, the following:

- the procedures adopted for short-term and long-term validation, and the adequacy of these procedures;
- the use of experimental laboratory and field data;
- the use of natural radiological analogs, as well as analogous non-radiological chemical events, in the validation;
- the use of data from existing deep large excavations and natural caves, and the time period over which such information applies;
- consideration of the extent to which the models can be validated generically, and the extent to which they can be validated with site-specific information;
- criteria for deciding what constitutes sufficient validation;
- implications of any gap between the time scale of possible validation experiments and the required predictive time scale for modelling;
- the range of validity of the models with respect to parameter ranges as an indication of robustness;
- additional research that might be needed or be useful for model validation.

6.4 Scenario and Sensitivity Analyses

The EIS should discuss the use of scenario and sensitivity analyses for the purpose of evaluating i) the effect of uncertainties in the physical parameters, ii) the effect of uncertainties in the model structure, and iii) the expected behaviour of the Multiple Barrier System to various possible physical scenarios. It should also discuss how this information can help in developing the insight and understanding needed to identify good sites as well as poor sites. Results should be presented, wherever possible, in the form of variations in space and time of critical parameters or quantities wherever possible. Aspects investigated should include, but not be limited to, the following:

- the effect of inclusion or exclusion of individual processes and mechanisms in a scenario, or the effect of uncoupling of individual processes from others;

- the effect of variation or uncertainty in individual physical, chemical, or biochemical parameters;

- the effect of spatial averaging of discrete physical features such as fractures and fracture zones to obtain bulk physical parameters;

- the effect of neglecting the time-dependence of individual parameters;

- the effect of reduction in the dimensions of models.

The discussion of the scenario and sensitivity analyses should include, but not be limited to, the following points:

- the identification of the relevant physical, chemical, and biological factors to be included in a particular scenario, and the justification for rejecting other factors;

- the criteria for the selection or rejection of scenarios;

- descriptions of the scenarios selected;

- the procedure for obtaining the governing parameters and their ranges, and the justification for the selection of these parameters and ranges;

- the procedure for analyzing and comparing different scenarios;

- the meaning and interpretation of results.

6.5 Disposal Vault Performance Modelling

The EIS should explain and justify the use of mathematical modelling to evaluate the performance of the generic Multiple Barrier System. The discussion should be organized according to suitable time scales. Specific issues pertaining to risks to the health of humans and to the natural environment raised in Sections 2.1 and 3.2 should be considered. Uncertainties from all sources expected to reside in the model results, and the effect of these uncertainties, should also be discussed. In the discussions of technical aspects, the overall objective of modelling should be kept in mind.

The procedures used for the generic performance assessment of the disposal vault should be compared with performance assessment procedures used by other countries. The advantages and disadvantages of differing approaches should be outlined.

All simulated results should be presented as functions of space and time, and portrayed with respect to the initial (pre-construction) condition. A rationale for presenting these simulated results in a certain form (e.g. mass release from the vault, concentrations of various constituents at certain points in the system, radiation exposure of biological organisms, risk of excess radiation at specified points, etc.) should be provided.

The EIS should also outline suitable quality assurance procedures developed so that modelling results can be reproduced and verified by independent parties.

The components, systems, processes and mechanisms that are of interest in the performance assessment modelling include, but may not be limited to, those outlined in Section 6.11.

6.51 The Short Term

The modelling procedure to evaluate the short-term response of the physical system(s), and the scenarios modelled, should be described. For this purpose, the short term may be subdivided into suitable sub-intervals, for example:

- the construction stage;
- the loading stage;
- the immediate (monitored) post-closure stage.

The discussion of the short-term modelling should include, but not be limited to, the following:

- a statement of the objectives;
- a list of the processes and mechanisms that are considered to be relevant for the short term, and a justification for the choice;
- the degree of coupling assumed between the selected processes;
- the spatial scale that is considered to be relevant for the short term;
- an assessment of what is realistically achievable and what is not achievable by modelling over the short term.

6.52 The Long Term

The modelling procedure used to evaluate the long-term response of the physical system(s), and the scenarios modelled, should be described. For the long term, responses should be modelled, at least, for the following external conditions:

- unchanged external conditions;

- the occurrence of possible long-term changes in the geosphere and biosphere (e.g. global warming, post-glacial isostatic rebound, renewed glaciation) and associated changes in ecosystems;

- the occurrence of catastrophic or unusual events (e.g. earthquakes, meteorite impact).

The discussion of the long-term modelling should include, but not be limited to, the following:

- a statement of the objectives;

- a list of the processes and mechanisms that are considered to be relevant for the long term, and a justification for the choice;

- the degree of coupling assumed between the selected processes;

- the spatial scale that is considered to be relevant for the long term;

- an assessment of what is realistically achievable and what is not achievable by modelling over the long term.

Particular care should be taken in discussing the long-term performance modelling because this type of modelling differs fundamentally from the other mathematical modelling activities, and because the long term transcends the time scale of recorded human experience. The discussion should include, but not be limited to, the following points:

- the validity and reliability of long-term performance modelling in general, in view of the limited experience and the limited validation that is possible;

- limitations of long-term predictive modelling due to model structure (i.e. the selection of processes and mechanisms);

- limitations of long-term predictive modelling due to parameter and data uncertainty;

- methods for quantifying predictive uncertainty and errors, and for relating predictive uncertainty to parameter and data uncertainty;

- the adequacy and validity of the adopted methods for dealing with parameter uncertainty over the long term;

- the degree of confidence in the long-term predictions, and the method chosen to express this degree of confidence;

- any special measures taken to enhance the reliability of long-term predictive modelling;

- the interpretation and meaning of the results produced by the models for the long term.

The discussion of short-term and long-term performance modelling should lead up to an overall assessment of the safety of the concept (the generic disposal system) under conceivable conditions and scenarios that might arise.

7. CONCEPT IMPLEMENTATION

In addition to developing an acceptable concept for the long-term management of nuclear fuel waste, the EIS should discuss the strategy and methodology for the implementation of the concept in a comprehensive manner. This discussion should include i) methods to characterize a generic site, ii) a discussion of the site selection process, iii) a description of the disposal facility, iv) a description of the transportation system, v) measures for environmental protection, vi) measures for occupational protection, vii) approaches for the monitoring of performance and of possible impacts, viii) measures for emergency planning, and ix) a cost estimate of the concept. As well, the EIS should investigate ways of involving the public in activities associated with concept implementation.

Due to the lack of experience in the implementation of a disposal facility of this magnitude, and the conceptual nature of information concerning a potential site and transport route, the EIS should include information based on work already conducted by the proponent with respect to realistic reference sites representative of different types of communities. This should be done as scenario analyses to give some specificity to the generic implementation of the concept.

The proponent should also make use of appropriate case studies of the implementation of major projects in Canada that may assist in the understanding of the concept implementation, in particular, an understanding of the social and economic aspects of such implementation. These case studies should involve analyses of actual activities that can be compared to activities associated with concept implementation. For example, mining developments, especially uranium mines, construction and operation of nuclear power plant facilities, and toxic waste management facilities may be used in part as analogs to certain activities related to concept implementation.

7.1 Site Characterization

The EIS should demonstrate a capability for investigating and characterizing actual candidate sites for the safe and acceptable disposal of nuclear fuel waste. Both natural and socio-economic aspects as well as their interrelationship should be considered. Characterization procedures should include criteria for determining when an actual site satisfies, or how it could be modified to satisfy, the generic requirements for safety and social acceptability. Criteria for rejection of a site should also be stated. In the case of multiple candidate sites, the characterization should indicate procedures and criteria for ranking sites, including the involvement of the public in these procedures.

7.11 Characterization of the Natural Environment

The EIS should discuss the investigation and characterization of natural environmental aspects of candidate sites including possible changes to the rock mass and site characteristics due to invasive site characterization and verification techniques. This discussion should include, but not be limited to, the following:

- the properties of and the various processes occurring in the host rock mass and surface environments of the candidate sites that are to be used in site characterization, and the reasons why these properties and processes were selected;
- a demonstration that appropriate techniques have been developed, tested, and are available for characterization of these properties and processes;
- a demonstration that appropriate techniques have been developed, tested, and are available for mapping these properties in three-dimensional space;
- a description of methods to be used to generate data for any potential future site, including specified sampling density, measurement frequency, mapping techniques, and criteria for establishing and testing the precision of site-specific data;
- an analysis of data limitations due to the choice of measurement interval, sampling density, and measurement technique, and due to data interpretation, and the consequences of these limitations;
- a description of methods used to identify and characterize fracture systems and major fracture zones;
- the extent to which geophysical depth sounding, and airborne and satellite remote sensing should be used for site characterization, and the integration of remote and on-site observation in site characterization;
- an analysis of the uncertainties involved in the identification and characterization of site-specific processes and properties, and the consequences of these uncertainties;
- the criteria, and the hierarchy in which the criteria are applied, for acceptance or rejection of candidate sites on the basis of physical, chemical and biological site

characteristics.

7.12 Characterization of Socio-economic Conditions

The discussion of the investigation and characterization of social, economic, and cultural conditions of candidate sites should include, but not be limited to, the following:

- social, economic, and cultural characteristics of candidate sites that are to be used in site characterization, and the reasons why these characteristics were selected;
- the location and extent of pre-existing human activities;
- the views of various public groups represented at the candidate sites and elsewhere, including the views of aboriginal peoples;
- an analysis of data limitations and the consequences of these limitations;
- an analysis of the uncertainties involved in the identification and characterization of candidate sites on the basis of social, economic, and cultural considerations, and the consequences of these uncertainties;
- a demonstration that appropriate techniques have been developed, tested and are available for sufficient description of all relevant characteristics and interactions occurring in the human environment of the candidate sites;
- the criteria, and the hierarchy in which the criteria are applied, for acceptance or rejection of candidate sites on the basis of social, economic, and cultural characteristics of the site, and the ability to describe those characteristics.

7.13 Modelling of the Natural Environment

The EIS should describe and discuss in detail the methods that may be used to integrate data from specific sites, and to translate these data into quantities required as input for computational models. Consideration should be given to specific issues raised in Section 6.0, where appropriate. This discussion should include, but not be limited to, the following:

- the methods used to assess the effects of any loss of information, due to data averaging or smoothing, during data translation;

- the consequences of uncertainties in site-specific data on the assessment of disposal vault performance;
- the methods to calibrate generic models against site-specific data on relevant space and time scales;
- the effect on site-specific simulations of the assumptions inherent in generic models;
- the methods to assess the impact of all factors of uncertainty on the reliability of assessed risk;
- the quality assurance procedures to guarantee that results of analysis can be verified or reproduced by independent parties.

7.2 Site Selection Process

The EIS should discuss options for a siting process for selection of a disposal facility site and transportation routes, should the concept be determined to be safe and acceptable. This discussion should include the following:

- the use of past and current site selection methods, processes, and experiences (e.g. siting of low-level radioactive wastes and toxic waste treatment facilities);
- a framework of ethical considerations for site selection;
- identification of a variety of community decision-making structures, and processes for the incorporation of these decision-making structures into site selection decisions;
- the criteria used to site the disposal facility and transport routes, the application of these criteria, and site elimination criteria;
- potential availability of sites in Canada;
- integration of socio-economic and biophysical criteria;
- the integration of the site investigation and characterization with a site selection process.

7.3 The Proposed Disposal Facility

The EIS should describe the proposed disposal facility, complete and at various phases of development, and discuss the major activities associated with the development of the disposal facility including site preparation, construction of surface, underground and auxiliary facilities, operation, decommissioning, and site restoration. This discussion should also include possible approaches to disposal facility management options, and labour and resource requirements.

7.31 Management

The EIS should discuss possible approaches or options for the overall management structure of the generic disposal facility identifying responsibility and accountability through all phases of development. This discussion should include, but not be limited to, the following:

- scheduling of all phases of development including target completion dates;

- identification and specification of conflict resolution and proposed dispute settlement procedures to resolve differences between agencies, communities and contractors, and between labour and management;

- identification of community involvement mechanisms;

- the organizational structures in other countries for the disposal of nuclear fuel waste, with comment on the possible applicability of such structures in the Canadian context;

- the organizational structures for other types of toxic waste, in Canada or elsewhere, as possible analogs for the disposal of nuclear fuel waste.

7.32 Activities

The EIS should describe the activities associated with the implementation of the various phases of the generic disposal facility with particular attention given to the phases associated with the storage and handling of nuclear fuel waste. This description should include, but not be limited to, the following:

- comprehensive description of activities related to each phase (i.e. site preparation, surface, underground and auxiliary facilities, operation and decommissioning);

- need for local infrastructure;

- transportation of construction materials, equipment, etc. to and from the generic site;

- interim storage and handling of nuclear fuel waste at the disposal centre;

- emplacement of nuclear fuel waste in the disposal vault.

7.33 Labour and Resource Requirements

The EIS should define and discuss in detail the anticipated labour and resource requirements for the various phases of disposal facility development. Particular attention should be given to the possible employment of local residents. This discussion should include, but not be limited to, the following:

- employment and personnel policies related to the utilization of local, regional and/or transient labour force;

- labour force size and skill requirements;

- educational upgrading and training programs (especially for local and regional labour force);

- schedule of transient worker influx(es);

- options for living accommodation for a transient labour force;

- transportation of transient workers to and from the disposal facility site;

- general estimates for resource requirements.

7.4 The Proposed Transportation System

The EIS should describe and discuss in detail possible approaches or options for the transport of nuclear fuel waste from storage facilities to underground emplacement. The present regulations for the transport of nuclear fuel waste should be described, and a discussion of the adequacy of these regulations as they apply to the proposed transportation system should be given. The EIS should also describe the existing transportation system of nuclear fuel waste in Canada, and discuss any additional requirements that may be imposed on the existing system due to the proposed transport system. The EIS should discuss how the proposed transportation system compares with similar nuclear fuel waste transportation systems in other countries, in particular in the areas of transportation procedures, regulations and planning.

The EIS should describe the various components of the proposed transportation system and their operation throughout all appropriate stages of concept implementation. This description should include the following: the proposed transport container system, transportation management, the operation of the transportation system, and labour and resource requirements.

In order to gain a realistic understanding of the transport of nuclear fuel waste to a generic disposal site, the EIS should also provide appropriate case studies of actual programs for the transport of hazardous materials in Canada. These case studies should attempt to reflect the types of conditions and circumstances (e.g. changes in population density, degree of proximity and adequacy of local emergency response systems, differences in geographic conditions, changes in political jurisdiction, etc.) under which the proposed transportation system may have to operate.

The EIS should also describe and discuss the possible risks associated with the proposed transportation system, and how these risks may be distributed along transport routes. Reference should be made to appropriate issues on risks to humans, human communities, the work site and the natural environment raised in Sections 2.1 and 3.2.

As well, the EIS should discuss the way that the public, especially residents located along potential transport routes, may be involved in the development and operation of a transport system. Case studies may also provide assistance in addressing the question of public involvement.

7.41 The Proposed Transport Container System

The EIS should describe the proposed transport container system, and provide a comparison of this system with alternative container systems for the transport of nuclear fuel waste.

The EIS should describe and justify the design and manufacturing criteria applied to the container system. The discussion should include, but not be limited to, the following:

- the selection of container design including provisions for change and future improvements;
- the selection of structural materials for the container system including present and future availability of materials, provisions for change, and the justification of the selection of materials including those materials which have no known natural analogs;
- the suitability of the designed container system for the selected method of handling and transferral;

- the possibility of a dual purpose container system suitable for transport and emplacement;

- the inspection procedures and quality control for all stages from fabrication to operation.

The EIS should discuss the circumstances and mechanisms leading to all possible causes of container breaching, or release of radionuclides and other contaminants during loading, unloading and in transit. Measures to prevent the possibility of breaching, and to minimize its effects should be described. The EIS should describe in detail the test procedures and the data used in these procedures, and the predicted performance of the container system, taking into account the probable modes of failure. This should include the following:

- a definition of container failure;

- a description of possible models for container failure;

- a discussion of mechanisms that may result in weakening or premature aging of materials.

7.42 Management

The EIS should describe and discuss in detail possible approaches or options for the overall management of the proposed transportation of nuclear fuel waste from storage to its emplacement in a disposal vault. The EIS should also discuss responsibility and accountability for all components of the transport system. This discussion should include, but not be limited to, the following:

- transport across political borders;

- identification and specification of conflict resolution and proposed dispute settlement procedures to resolve differences between agencies, communities and contractors, and between labour and management;

- identification of community involvement mechanisms in transport decisions.

7.43 Operation

The EIS should describe all activities associated with the operation of the proposed transportation system. This discussion should include, but not be limited to, the following:

- proposed modes of transport;
- criteria for acceptance and rejection of transport routes;
- the volume, frequency and timing of shipments;
- monitoring of the location of the transport unit;
- a definition of an emergency, measures to be taken in the event that an emergency occurs, and the effects of such emergencies on costs and safety;
- criteria and procedures for returning the nuclear fuel waste to storage facilities in the event of an emergency;
- demonstration that considerations of climate, terrain, road and other physical conditions affecting transportation in typical Canadian settings have been thoroughly examined;
- public involvement with decisions concerning the choices of transport modes, routes, and methods of operation.

7.44 Labour and Resource Requirements

The EIS should discuss the labour and resource requirements for the construction of transportation components, and the maintenance and operation of the transportation system. This discussion should include, but not be limited to, the following:

- labour force skill requirements, and availability of skilled workers;
- initial and ongoing training of transport workers;
- general estimates for resource requirements.

7.5 Environmental Protection

The EIS should discuss the mitigative measures that may be required for the protection of the natural environment from the activities associated with the development and operation of the disposal facility, and with the transport of nuclear fuel waste. The discussion should incorporate issues pertaining to risks raised in Sections 2.1, 2.4 and 3.2 where appropriate, and include, but not be limited to, the following:

- consideration of radiological and non-radiological emission and waste management;

- radiation exposure regulations;
- environmental standards for emissions and waste;
- recognition of multiple resource use and land use;
- protection of critical habitats, and rare and endangered species;
- measures to be taken to restore the natural environment during disposal facility decommissioning.

7.6 Occupational Protection

The EIS should discuss the measures that are required to protect workers during all activities associated with the development and operation of the disposal facility, and during the transport of nuclear fuel waste. The EIS should describe the required standards of performance, and discuss the development of occupational safety and health training programs to assure these standards are met. Appropriate issues raised in Sections 2.1, 2.4 and 3.2 should be included in this discussion. This discussion should include, but not be limited to, the following:

- occupational safety standards;
- safety measures and their enforcement;
- measures to assure safety of workers during handling of used nuclear fuel;
- safety record of current mode of transport of nuclear fuel waste.

7.7 Monitoring

The EIS should describe and discuss in detail the possible approaches and options for the monitoring of possible changes in the work site, in human communities, and in the natural environment that may result from all phases of disposal facility development and operation, and from the transport of nuclear fuel waste. As well, a description of monitoring methods to assess the performance of components of the disposal facility and of the transportation system (i.e. the sealed vault, transportation container, etc.), and to anticipate early failure of important components, should be included.

The EIS should also outline in detail how an overall monitoring program is incorporated into all activities associated with disposal facility development, operation and decommissioning, and with nuclear fuel waste transport, to assure that the most appropriate parameters are monitored, that appropriate reporting and response mechanisms are in place, and that important components are not overlooked. The EIS should also discuss the ways in which local residents will be involved in any monitoring program.

This description and discussion of possible approaches and options for monitoring should include, but not be limited to, the following:

- the extent in time and space for each component of the overall monitoring program, and the justification for the extent;

- the subjects and parameters monitored, and the criteria used in their selection;

- the storage of records and the communication of monitoring results;

- a statement of the criteria for tolerable deviations from predicted behaviour;

- integration of monitoring results with other aspects of the disposal concept including baseline conditions, assessment of possible impacts, and performance assessment of the Multiple Barrier System;

- application of monitoring results to remedial measures, mitigation and other phases of disposal facility functions;

- consideration of experience gained from previous and present monitoring programs where appropriate.

7.8 Emergency Planning

The EIS should discuss possible approaches or options to a planning and response system for emergencies that may arise during all activities of disposal facility development and operation, and during the transport of nuclear fuel waste. This discussion should include, but not be limited to, the following:

- identification and ranking of the full range of emergencies that might affect the labour force, the surrounding public and the public at large;

- levels of emergency response, and the types of emergency response systems that may be required;

- responsibilities and financial obligations of parties involved, both public and private, including dispute settlement and compensation mechanisms;
- the need for emergency equipment and public warning systems;
- possible accident scenarios, and the treatment facilities, local and otherwise, that may be required;
- contingency planning.

7.9 Cost Estimate

The EIS should provide an estimate of the internal cost of the concept, including all costs of planning, financing, building, operating, and decommissioning. The cost of monitoring, possible mitigation and compensation should be included.

The EIS should also, at least in general terms, address the question of external costs associated with the concept, including those measurable costs that would fall upon municipalities and other jurisdictions, and the extent to which these external costs would be off-set by a reduction of risks, hence associated social costs.

8. IMPACTS

The potential social, economic and environmental impacts of all phases of the implementation of a disposal facility and of the contents of a disposal vault on humans, human communities, the work site and the natural environment should be described and discussed in detail. These potential impacts may take on various forms and significance, and have various risks, magnitudes and geographic extents, as well as complex interrelationships and timings. This description and discussion should therefore be done clearly, unambiguously and, wherever possible, quantitatively. Various public groups in Canada, such as residents of northern communities, aboriginal peoples, people living near possible transport corridors, etc. may have different viewpoints on the forms and significance of these possible impacts. The proponent should consider these different viewpoints when presenting its EIS, particularly the viewpoints of aboriginal peoples and the viewpoints of other public groups that have a significant potential of being impacted.

It would be useful if such description and discussion were organized according to key time and space intervals, and to identifiable stages of concept implementation (e.g. initial or baseline conditions, disposal facility construction, decommissioning, disposal vault loading, after vault closure, etc.).

Because the time scale for the actual construction and operation of a disposal facility at a specific site is in the order of several human generations, many impacts may at present be largely unknown or incompletely defined. This is especially the case for this review given its conceptual nature and the absence of a specific site. Therefore, it is important to recognize the limitations and the boundaries of present knowledge as it applies to social, economic, scientific and technical considerations of the disposal concept.

In response to these limitations and unknowns, the proponent should develop a long-term comprehensive strategy for the evaluation of possible impacts from concept implementation and from the contents of a disposal vault. The proponent should outline plans for how this strategy will:

- establish what is currently known about possible impacts;

- acquire and incorporate new knowledge or information (i.e. scientific, technical, social, economic, etc.) as it becomes available through additional research and consultation, and during site characterization and concept implementation;

- allow for changes in design and implementation of the concept;
- adjust equitably and with relevance to changes in social values and social priorities;
- determine the conditions that would signal the attainment of various acceptable and unacceptable social and economic outcomes;
- reduce or eliminate adverse impacts, if possible.

The public and other participants in this review have approached the issue of nuclear fuel waste management with different views about the appropriate way to proceed, based largely on differences in ethical and moral perspectives. These ethical and moral perspectives, along with various social issues, as evidenced by presentations to the Panel at the scoping meetings, are as important as scientific, technical and economic considerations, and therefore form an integral part of this review. The proponent should include in this strategy an investigation of how relatively narrow and focused considerations of a scientific, technical or economic nature should be viewed in the much broader context of ethical, moral and social considerations.

8.1 Strategy for Impact Evaluation

The proponent should present and describe in detail a long-term comprehensive and adaptive strategy for the evaluation of possible impacts from concept implementation, from the transport of nuclear fuel waste, and from the contents of a disposal vault. The proponent should discuss how this strategy will be fair in process, flexible in its response to new information, and reflect an understanding of the ethics and values of review participants, in particular, those groups that could be most affected by the disposal concept. The EIS should discuss how the current knowledge base is enhanced and updated as new information is incorporated, and how performance assessment and other modelling is continually adjusted to reflect this new information. The proponent should also discuss how this strategy will allow for changes in the design of the concept, and in regulatory criteria that are most likely to determine whether a specific site is still suitable or should be abandoned.

The description and discussion of this strategy and of the possible impacts from the disposal concept should include, but not be limited to, the following:

- assumptions upon which predictions of impacts are based, and the uncertainties of these predictions;

- the extent and significance of knowledge deficiencies, and how such deficiencies may affect predictions of impact;

- the identification of areas where further research or data collection is required to improve the understanding and confidence in predictions;

- characterization of the significance given to uncertainties and risks;

- consideration of unexpected problems such as malfunction and anomalous environmental events, and the assessment of the probability of these unexpected problems;

- identification of any limitations of impact analyses and assessments;

- identification of important indicators used to assess possible impacts;

- flexibility to respond with changes in the design of the concept as new information is acquired and as site attributes are discovered;

- flexibility to respond to changes in regulatory criteria;

- ability to continuously adjust the performance assessment and other modelling to reflect new information;

- investigation of monitoring procedures, and of the ability to repair failed components of the disposal system in order to minimize the possibility that unplanned or unexpected events will compromise the integrity of the disposal system;

- options and measures to avoid, minimize, mitigate or compensate for these impacts, and the effectiveness of adopted measures;

- identification of residual impacts remaining after all mitigating measures have been taken;

- investigation of the accumulation of impacts from concept implementation and from other unrelated human activities. This should include, but not be limited to, the extent in time and space of these impacts, key elements within human communities and the natural environment that could be affected, bioaccumulation of radionuclides and other contaminants, effects of continuous low-level radiation exposure, and a suggested design of a monitoring scheme that includes the provision for following the accumulation of impacts;

- independent review procedures, with appropriate public involvement, to appraise decisions made and, if necessary, to revise concept design;

- a consideration of alternatives for each major decision made.

An important initial step in the development of a strategy is to establish the current knowledge base for possible impacts resulting from a disposal facility. This knowledge base should be comprised largely of what is actually known or could be determined in a straight forward manner, such as research, past experience, etc., as opposed to modelled predictions.

8.2 Current Knowledge Base

The EIS should document and discuss in detail the present state of knowledge about possible impacts of concept implementation and the contents of the disposal vault on humans, human communities, the work site and the natural environment.

8.21 Case Studies

As in the case of concept implementation and foremost in the understanding of the possible impacts, the proponent should make ample use of appropriate case studies or past experiences of the impacts, particularly socio-economic impacts, of ongoing or completed major projects in Canada. These case studies may enhance the reader's understanding of possible impacts, and most importantly, may form a realistic perspective for the determination and evaluation of impacts in this conceptual review. The case studies should involve analyses of the impacts of actual activities that can be reasonably compared to activities that may be associated with concept implementation. For example, mining developments, especially uranium mines, construction and operation of nuclear power plant facilities, and toxic waste management facilities could be used in part as analogs to some of the possible impacts resulting from activities associated with concept implementation. As well, the proponent should include, where appropriate, discussions on aspects of these major projects which may have resulted in environmental, socio-economic and cultural impacts on aboriginal peoples and the residents of other communities residing in impacted regions.

The analyses of these case studies should include where appropriate, but not be limited to, the following:

- justification of the selection of the case studies under consideration;

- justification of the selection of specific activities or aspects of these major projects used as analogs for comparative purposes;

- evaluation of the changes or impacts, over appropriate time periods, that could be viewed directly or indirectly as having resulted from activities or aspects of the major projects selected as analogs;

- identification of the geographical extent of changes or impacts associated with these projects;

- determination of important indicators that have signalled these changes or impacts;

- conclusions on what can be learned as part of the current knowledge base with respect to possible social, economic and environmental impacts of the concept.

In the evaluation of changes or impacts resulting from activities or aspects of projects used as case studies, the proponent should make use of appropriate characteristics outlined in a subsequent section on baseline conditions (Section 8.24). For example, the proponent should, where appropriate to the scale and geographical extent of a project, consider: human population size and characteristics, the physical and psychological health of the local population, local economies and infrastructure, local employment situation, land use patterns, valued areas and protection of valued natural resources, local level of economic development and education, multiple resource use and integration of competing uses, and ethical and moral considerations, if possible.

8.22 Scenarios

In addition to the analyses of the results of case studies to enhance the current knowledge base, the EIS should study and model carefully selected scenarios, representative of a variety of appropriate social, economic and cultural characteristics of candidate sites including those characteristics to be used in site characterization (Section 7.12), to determine possible impacts. For example, realistic reference sites and communities, at various levels of development, ranging from wilderness areas to communities that are economically developed, could be considered.

The proponent should study and model an additional variety of scenarios to determine possible impacts of the disposal concept. These scenarios should include various types and sizes of appropriate ecosystems, various levels of growth in electrical power generation by nuclear power plants, the effects of local and global climate change, etc.

The proponent should identify the key indicators that could signal unacceptable social, economic and environmental impacts or outcomes, and the conditions that could lead to these impacts or outcomes. The proponent should also investigate methods to prevent or mitigate such impacts or outcomes.

8.23 Scenarios and Analogs in the Long-term

The long term, or the time period after the disposal vault has been closed and the disposal site decommissioned, transcends human experience. Particular care should be taken in the selection of scenarios and analogs to give an appropriate assessment of impacts on humans and the natural environment in the long term. For example, analogs, natural and otherwise, including natural deposits of radioactive elements, should be considered for the evaluation of the concept or components of the concept.

8.24 Baseline Conditions

In addition to establishing the current knowledge, it is necessary to establish reference baselines against which actual and expected impacts from concept implementation, nuclear fuel waste transport, and vault contents can be measured. To this end, local human communities and the natural environment, particularly regional ecosystems, should be described in terms of those parameters that are relevant to the assessments of the environmental and socio-economic impacts in the short term and the long term. The EIS should therefore describe and distinguish the various sets of baseline conditions that are required for these assessments, their relevant extent in space and time, and the methods and criteria used in the selection of these baseline conditions. Where possible, the ranges of the relevant human and natural parameters in typical candidate site environments should be specified.

In the selection of the various sets of baseline conditions, consideration, where appropriate to a particular set, should be given to, but not be limited to, the following:

- present human population size and characteristics;

- physical and psychological health of the populations;

- community and social health;

- local economies and infrastructure including housing, transportation networks, health services, recreational facilities, utilities and energy supply;

- employment situation including types and levels of skills, incomes, employment trends, and educational and training facilities;

- land use including current plans, legislation, trends, valued areas (e.g. recreational, heritage, economic, natural, archaeological, and spiritual), aboriginal views on land use, and aboriginal land claims;

- key physical (e.g. climate, weather), biological (e.g. fish, wildlife), chemical (e.g. water quality, soil chemistry), and energy (e.g. main primary producers, important detritivores) components, and important relationships among these components;

- biological energy flows, critical transfer points between trophic levels, and radionuclide pathway mechanisms;

- biological community indices such as species habitat, diversity, distribution and abundance;

- successional stage(s) and the vulnerability to disruption of succession (i.e. the progressive change in a biological population as a result of the response of the members of the population to the environment);

- key indicators of change in human communities and the natural environment;

- existence and vulnerability of rare or endangered species;

- land surface features, including soils, sediments, topography and functional relationships between the geosphere and the biosphere (e.g. nutrient cycling, hydrological patterns, habitat);

- atmospheric conditions, including prevailing weather patterns;

- surface water hydrology and limnology for still water and flowing water systems, especially key factors that can affect contaminant transport, fate and toxicity (e.g. seasonal flow events, lake temperature, stratification, lake sediment chemistry and lake trophic status);

- chemical and radiochemical composition of the groundwater and surface waters.

The changes in the human communities and the natural environment (independent of the establishment of the disposal facility) that can be expected, and how these changes may affect baseline conditions, should be discussed. This discussion should include, but not be limited to, the following:

- human activities;
- natural biological succession;
- climate change;
- post-glacial adjustments;
- possible changes in regional groundwater flow systems that could result from climatic or geologic changes.

In the evaluation of impacts and the development of a strategy to assist in this evaluation, the proponent should consider important issues raised in the following sections on health, and possible short- and long-term impacts.

8.3 Health Considerations

The EIS should discuss the potential health impacts of radiation, radionuclides and other contaminants on humans and various components of the natural environment in the short term and the long term. Consideration should be given to specific issues raised in Sections 2.1 and 3.2, where appropriate. This discussion should not be restricted to mortality and should include, but not be limited to, the following:

- natural background radiation;
- non-radiological and radiological health impacts associated with the construction, operation, and closure of the disposal facility, and with the transportation and handling of nuclear fuel waste;
- potential health impacts from radiation, radionuclides and other contaminants on humans and other biota in the surrounding and in more distant areas;
- ability to measure and monitor physical and psychological health, and limitations to this ability;
- individual stress and community stress resulting from public concerns regarding potential health impacts.

The EIS should also review what is known about the effects of radioactivity on non-human biota, including sublethal but possibly mutagenic effects of chronic low-level exposure to high-LET (Linear Energy Transfer) radiation, in light of existing and proposed regulations. Knowledge about these effects should then be used to evaluate potential short- and long-term impacts on biotic populations and communities, and on ecosystems.

8.4 Possible Short-term Impacts

The short term is understood to be the time period of planned activities at a disposal facility which includes site characterization and preparation, construction, the loading and closure phases, the site decommissioning phase, and a post-closure monitoring phase.

Significant impacts on humans, human communities and the natural environment as a result of disposal facility construction, vault loading, and closure, and the transport of nuclear fuel waste, should be described and quantified. As well, the local and regional significances of these impacts should be identified.

Also, the conditions under which discharges of radionuclides and other contaminants might possibly occur, the probability of such occurrences and the possible consequences on humans and the natural environment as a result of these occurrences should all be considered.

The assessment of the possible impacts leading up to vault closure should follow a comprehensive approach incorporating important areas of human concerns, values and institutions, and the natural environment. Particular attention should be given to the viewpoints of various public groups, in particular, those groups that may be most affected by concept implementation.

The EIS should present a methodology to assess possible impacts on representative reference communities, organized and unorganized, and on users of essentially wilderness areas. Recognition should be given to the integration of competing resource and land use by current human and natural activities in these reference communities, and the possible changes that could occur in this integration due to concept implementation. Any inadequacies in this methodology to assess possible impacts should be outlined and discussed.

In the development of this methodology, the following factors should also be considered:

- local population size, characteristics, growth and structure;

- local population mobility;

- local lifestyles, values and traditions;

- local employment and business, including cottage industries, tourism, hunting and harvesting;

- hiring policies;

- individual and community health and local health services;

- education facilities, and training programs for local residents;

- political structures and decision-making powers;

- local level of development;

- local infrastructure, including road systems, utilities and communications, health facilities and emergency medical services, police and emergency services, and recreational facilities;

- land and resource use, and ownership.

In the consideration of possible impacts on the natural environment, the following factors should also be considered:

- effects of vault construction and operation on groundwater characteristics;

- effects on surface hydrology from transportation, construction and operation;

- changes in species diversity, distribution or abundance;

- selection of natural indicators;

- potential effects on soil and sediment chemistry, water and air quality.

In describing short-term impacts, the EIS should clearly state expected changes to the appropriately-selected baseline conditions as described in Section 8.24.

8.5 Possible Long-term Impacts

The long term is understood to be the time period after disposal vault closure and disposal facility decommissioning. Long-term impacts therefore relate primarily to unforeseen events, worse-than-expected conditions, or gradual changes in the natural environment that might cause discharges of radionuclides and other contaminants at unexpected rates. Conditions under which such discharges to the natural environment might occur, the risks of such occurrences, and the possible impacts, including the accumulation of impacts from other sources, on humans and the natural environment, should be described and discussed in detail.

The proponent should identify relevant physical, chemical and biological parameters that could indicate these possible impacts, and discuss the reasons for the selection of these parameters. Possible long-term changes in these parameters should be shown graphically.

Possible measures that can be taken in the shorter term that would tend to minimize, mitigate or compensate for potentially harmful long-term effects should be discussed.

The EIS should also discuss the ethical dimensions of disposal vault closure in relation to possible long-term impacts on humans and the natural environment.

The discussion of possible long-term impacts should include, but not be limited to, the following:

- long-term changes in the rock mass and the groundwater flow system due to the presence of the vault;
- possible long-term impacts of the vault and its contents on the surface environment under stable conditions;
- possible long-term impacts of the vault and its contents on the surface and rock mass environments under conditions of geologic change and atmospheric change;
- theories, models and other tools (including natural analogs) used to identify and assess long-term changes in the rock mass and surface environments;
- the physical, chemical, and biological parameters that could be used to express significant long-term environmental impacts;
- the scenarios used and assumptions made to predict possible long-term changes;
- the risk of a possible long-term impact occurring, and the basis for selection of risk figures;
- the reliability and the limitations of predictions of possible long-term environmental impact;
- the criteria adopted to determine when an environmental impact is significant, as well as those used to determine when the risk of a significant impact is sufficiently high to cause rejection of a site.

All discussions of potential long-term environmental impacts should include the corresponding risk figures to natural ecosystems and humans. Potential impacts should be expressed in terms that are readily understandable, such as:

- possible concentrations of radionuclides or other harmful substances at critical reference locations in the rock mass and surface environments;

- the potential radiological dose received by humans and other biota in the vicinity of a site, at critical points in time;

- possible long-term or chronic pollution effects and bioaccumulation in the food chain;

- the potential for additional cancers.

In describing long-term impacts, the EIS should clearly state expected changes to the appropriately-selected baseline conditions as described in Section 8.24.

APPENDIX

GLOSSARY OF TERMS

Adsorption - The physical or chemical bonding of molecules of gas, liquid or dissolved substance to the external surface of a solid, or to the internal surface if the material is porous in a very thin layer.

Advection - Transportation by the horizontal movement of air, e.g. moisture, pollutants, heat, etc.

Analog - A reference material or situation, which can be found in nature or in established societies, which has withstood the test of time.

Atmosphere - The gaseous envelop surrounding the earth.

Backfill - Material used to refill an excavation.

Baseline Conditions - An established reference against which impacts can be measured.

Bioaccumulation - An increase in tissue concentration relative to the exposure concentration, due to the rate of intake into a living organism being greater than the rate of excretion or metabolism.

Biofouling - The prolific growth of microbiota on some surface.

Biosphere - The portion of the earth and its atmosphere in which life can exist.

Breaching - An opening made by breaking down something solid, as a gap made in a wall or fortification; fissure.

Burial - Disposal of waste materials by depositing them in the earth.

Colloidal Migration - The movement of particles or aggregates through a gas, liquid or solid medium. The system is neither a solution nor a suspension.

Containment Failure - The breaching of a container through some sort of mechanical or chemical process.

Correlation - The statistical interdependence of parameters or their correlation. Auto-correlation refers to the use of a function to measure the statistical dependence of a parameter with itself. Cross-correlation refers to the use of a function to measure the statistical dependence of a parameter with another.

Corrosion Mechanism - The gradual wearing away of a substance by chemical action.

Critical Mass - The minimum mass of uranium of other nuclides needed for a self-sustaining chain reaction.

Data Translation - The conversion of site specific information into a form of language that can be used in computer modelling, without losing the sense of meaning.

Decommission - The process of removing a facility area from operation and decontaminating and/or disposing of it or placing it in a condition of standby with appropriate controls and safeguards.

Detritivores Components - The biological process by which microorganisms decompose dead organic matter to their original elements.

Disposal - The planned placement of radioactive waste in a repository without the intention of retrieval.

Dynamic Change - Active or energetic change in force or energy.

Eh - Oxidation potential

Embrittlement - The process of making or being brittle.

Enriched Fuel - Nuclear fuel containing more than the naturally-occurring concentration of the uranium-235 isotope; enrichment makes the fuel more reactive.

Food Chain - A sequence of organisms in a community, each of which uses the next (usually lower) member of the sequence as a food source, green plants being the ultimate basis for the sequence.

Future Generations - Offspring or descendants to come. A generation is normally accepted to be 25 years.

Geosphere - The mineral, non-living portion of the earth. The earth, excluding the atmosphere, hydrosphere and biosphere.

Global Warming - The effect which can be witnessed in a garden greenhouse in which shortwave solar radiation penetrates glass, but returning radiation from the ground (being of long wavelengths) is blocked by glass, thus raising air temperature in the greenhouse. The earth's atmosphere acts similarly, with returning radiation being largely absorbed by water vapour, carbon dioxide, and ozone.

Half-Life - The characteristic time taken for the activity of a particular radioactive substance to decay to half of its original value.

Health - Complete physical, mental, emotional and social well being. (World Health Organization)

Heterogeneities - The quality or character of being varied or different.

High-Level Waste - Radioactive waste that initially requires continuous active cooling in order to dissipate the internally generated heat. In Canada, the only waste categorized as high-level is spent fuel from the CANDU reactors.

Hydrogeology - The study of the geological factors relating to the earth's water.

Hydrosphere - The part of the earth which is composed of water: oceans, seas, the icecaps, lakes, rivers, etc.

Ionizing Radiation - Radiation which possess sufficient energy to either positively or negatively charge a neutral atom or molecule of substances through which it passes.

Isostatic Rebound - The vertical movement of sections of the earth's crust to achieve balance or equilibrium, e.g. the rise of the earth's crust following the period of glaciation.

Leaching - The removal of soluble constituents of rock or soil by the action of flowing water.

LET Radiation - The amount of energy lost by radiation as it passes through tissue (high Linear Energy Transfer implies a large loss of energy).

Limnology - The study of physical, chemical and biological components of fresh water.

Long Term - The long term covers the time period after vault closure and decommissioning of the disposal facility.

Microbiota - Microscopic organisms such as algae, animals, viruses, bacteria, fungus, and protozoa.

Modelling - An investigative technique using a mathematical or physical representation of a system or theory that accounts for all or some of its known properties.

Natural Environment - The ecosystem, in which the living and non-living interact to bring about circulation, transformation and accumulation of energy and matter.

Nuclide - A species of atom characterized by the constitution of its nucleus and hence by the number of protons, neutrons and the energy contents.

pH - A symbol for the degree of acidity or alkalinity of a substance, based on the number of hydrogen ions in a litre of the solution. pH is measured on a scale of 1 to 14 where 7 is taken to represent neutrality, less than seven is acidic and greater than seven is alkaline.

Radiation - Any form of energy propagated as rays, waves, or streams of energetic particles. The term is frequently used in relation to the emission of rays from the nucleus of an atom.

Radiation Exposure Limits - The maximum exposure to radiation that may be received by a worker or a member of the public in a year.

Radiocolloids - Radioactive particles or aggregates contained in a gas, liquid or solid medium. The system is neither a solution nor a suspension.

Radiolysis - The decomposition of a material by ionizing radiation.

Radionuclide - A radioactive particle - a species of atom which has a nucleus with the potential for radioactive decay. Any nuclide which emits radiation.

Regional Ecosystems - A community of interdependent organisms together with the environment which they inhabit and with which they interact.

Retrievable Storage - The emplacement of radioactive waste in a secure location with the intention of retrieving it.

Robustness - measures the ability of a model to perform accurately and reliably under a variety of conditions and parameters.

Seismic and Static Loads - Static load refers to stresses imposed on rock under normal circumstances and seismic load refers to stresses imposed on rock under seismic or elastic wave conditions, i.e. a simultaneous stretching and compression of the rock.

Short Term - The short term is understood to be the time period of planned human activities at a disposal facility site. It includes the period of the site characterization and preparation, construction, the loading and closure phases, and a post-closure monitoring phase.

Storage - The emplacement of radioactive waste in a secure location with the intention of retrieving it.

Surface Environment - Any heavily fractured or weathered zone at the top of the rock mass, surficial deposits, soils and living matter on or near the surface, shallow groundwater, surface water and the atmosphere.

Thermal Loads - The quantity of heat-generating materials placed in a given area or volume.

Transmutation - The change of dangerous radionuclides into other nuclides which would be short-lived and soon become stable.

Trophic Levels - The nutrient status of a water body.

Vault Environment - The surrounding conditions and influences within the vault.

Waste Transfer - The movement of radioactive waste from one area of containment to another.