Compilation of Technical Comments Submitted by Participants in the Federal Environmental Assessment Panel Review of the Nuclear Fuel Waste Management and Disposal Concept, with Responses

Prepared by Ontario Power Generation

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1 INTRODUCTION

This document is a compilation of technical comments made during the review of the Nuclear Fuel Waste Management and Disposal Concept conducted by a federal Environmental Assessment Panel. It is a printout from a Microsoft Access database.

Participant comments were identified from the following sources:

- submissions from the Scientific Review Group,
- submissions from federal government departments and agencies,
- submissions from scientific and technical organizations,
- submissions from non-government organizations, and
- submissions from individuals which were of a primarily technical nature.

The following types of comments were identified:

- technical shortcomings associated with the AECL disposal concept,
- technical comments on implementation of disposal that affect the technical work to be done, and
- suggestions of alternatives to disposal if they make a technical point.

Comments on transportation were not included. Comments on the same topic are grouped in the same category to facilitate the preparation of one response for the category.

The identification of comments, and the grouping of them into categories, was prepared for OPG by a consultant. Comments were identified as objectively as possible, nevertheless, it is recognised that other reviewers might have generated a somewhat different set of comments and categories. OPG believes that the present set is comprehensive and fairly represents the comments raised during the Environmental Assessment Panel.

This report also provides a brief OPG response to each group (category) of comments. This response is intended to provide OPG's perspective on developments since the Panel report was completed, on the relative priority of the issues raised (i.e when the comments would naturally be addressed if a repository program were initiated), and on current OPG activities in relevant topics. The present response is based on the technical progress as of 2003.

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7.03.02.02.08	Safety Assessment - Postclosure - Disposal System - SYVAC3-CC3 - Inappropriate Parameters
7.03.02.02.09	Safety Assessment - Postclosure - Disposal System - SYVAC3-CC3 - Ease of Review
7.03.02.02.10	Safety Assessment - Postclosure - Disposal System - SYVAC3-CC3 - Comparison with UTAP
7.03.02.03	Safety Assessment - Postclosure - Disposal System - Chlorine-36
7.03.02.04	Safety Assessment - Postclosure - Disposal System - Technetium-99
7.03.02.05	Safety Assessment - Postclosure - Disposal System - Radionuclide Speciation
7.03.02.06	Safety Assessment - Postclosure - Disposal System - Dispersivity

7.03.03	Safety Assessment - Postclosure - Vault
7.03.03.01	Safety Assessment - Postclosure - Vault - Conceptualization
7.03.03.02	Safety Assessment - Postclosure - Vault - Container
7.03.03.03	Safety Assessment - Postclosure - Vault - Parameters
7.03.03.03.01	Safety Assessment - Postclosure - Vault - Parameters - Instant Release Fraction
7.03.03.03.02	Safety Assessment - Postclosure - Vault - Parameters - Diffusion Coefficients
7.03.03.03.03	Safety Assessment - Postclosure - Vault - Parameters - Solubility Limits
7.03.03.03.04	Safety Assessment - Postclosure - Vault - Parameters - Buffer Anion Correlation Coefficient
7.03.03.03.05	Safety Assessment - Postclosure - Vault - Parameters - Mass Transfer Coefficient
7.03.03.04	Safety Assessment - Postclosure - Vault - Research
7.03.04	Safety Assessment - Postclosure - Geosphere
7.03.04.01	Safety Assessment - Postclosure - Geosphere - Conceptualization
7.03.04.02	Safety Assessment - Postclosure - Geosphere - Models
7.03.04.02.01	Safety Assessment - Postclosure - Geosphere - Models - GEONET
7.03.04.02.01.01	Safety Assessment - Postclosure - Geosphere - Models - GEONET - General
7.03.04.02.01.02	Safety Assessment - Postclosure - Geosphere - Models - GEONET - Velocity Scaling Factor
7.03.04.02.02	Safety Assessment - Postclosure - Geosphere - Models - MOTIF
7.03.04.02.03	Safety Assessment - Postclosure - Geosphere - Models - TRACK3D
7.03.04.02.04	Safety Assessment - Postclosure - Geosphere - Models - Well Model
7.03.04.03	Safety Assessment - Postclosure - Geosphere - Data Usage
7.03.04.04	Safety Assessment - Postclosure - Geosphere - Parameters
7.03.04.04.01	Safety Assessment - Postclosure - Geosphere - Parameters - General
7.03.04.04.02	Safety Assessment - Postclosure - Geosphere - Parameters - Sorption
7.03.04.04.03	Safety Assessment - Postclosure - Geosphere - Parameters - Groundwater Residence Time
7.03.04.04.04	Safety Assessment - Postclosure - Geosphere - Parameters - Hydraulic Properties
7.03.04.04.05	Safety Assessment - Postclosure - Geosphere - Parameters - Well Depth
7.03.04.05	Safety Assessment - Postclosure - Geosphere - Research
7.03.04.06	Safety Assessment - Postclosure - Geosphere - Scenarios
7.03.04.07	Safety Assessment - Postclosure - Geosphere - Waste Exclusion Zone
7.03.05	Safety Assessment - Postclosure - Biosphere
7.03.05.01	Safety Assessment - Postclosure - Biosphere - Conceptualization
7.03.05.02	Safety Assessment - Postclosure - Biosphere - Models
7.03.05.02.01	Safety Assessment - Postclosure - Biosphere - Models - BIOTRAC
7.03.05.02.02	Safety Assessment - Postclosure - Biosphere - Models - BIOTRAC Soil Model
7.03.05.02.03	Safety Assessment - Postclosure - Biosphere - Models - CALDOS
7.03.05.03	Safety Assessment - Postclosure - Biosphere - Data Usage
7.03.05.04	Safety Assessment - Postclosure - Biosphere - Parameters
7.03.05.04.01	Safety Assessment - Postclosure - Biosphere - Parameters - Dose Conversion Factors
7.03.05.04.02	Safety Assessment - Postclosure - Biosphere - Parameters - Transfer Coefficients
7.03.05.04.03	Safety Assessment - Postclosure - Biosphere - Parameters - Fish Ingestion Rate
7.03.05.04.04	Safety Assessment - Postclosure - Biosphere - Parameters - Concentration Ratios
7.03.05.04.05	Safety Assessment - Postclosure - Biosphere - Parameters - Occupancy Factors
7.03.05.04.06	Safety Assessment - Postclosure - Biosphere - Parameters - Food Intake Rates
7.03.05.04.07	Safety Assessment - Postclosure - Biosphere - Parameters - Stable Iodine
7.03.05.04.08	Safety Assessment - Postclosure - Biosphere - Parameters - Plant-Soil Concentration Ratio
7.03.05.05	Safety Assessment - Postclosure - Biosphere - Research
7.03.05.06	Safety Assessment - Postclosure - Biosphere - Gaseous Radionuclides
7.03.05.07	Safety Assessment - Postclosure - Biosphere - Traits of the Critical Group
7.03.05.08	Safety Assessment - Postclosure - Biosphere - Doses to Non-Human Biota
7.03.06	Safety Assessment - Postclosure - Software Quality Assurance
7.03.07	Safety Assessment - Postclosure - Input Data Quality Assurance
7.03.08	Safety Assessment - Postclosure - Uncertainty
7.03.09	Safety Assessment - Postclosure - Verification and Validation

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2 PROJECT MANAGEMENT

2.01 Project Management - Timing of Disposal

PARTICIPANT COMMENTS

Campaign for Nuclear Phaseout

include an examination of long term above ground storage. The impact on levels of radioactivity in retaining nuclear waste on the surface for an additional 50 to 100 years before moving should be reviewed. [Comment 1793, Source Document pub027, Page 24, Section III.D]

Concerned Citizens of Renfrew County and Area

Most significantly, the EIS does not provide a credible analysis of the potential for extended storage of fuel wastes at existing sites to reduce radiation exposure to workers and the general public. On page 262 it is stated that "increasing the out-of-reactor time for the used fuel from 10 to 40 years would reduce the estimated external dose from cask handling by a factor or two." The assumptions and calculations used to arrive at this conclusion are not detailed, and it appears inconsistent with a negative exponential trend in waste activity. A sensitivity analysis of the effects of varying periods of out-of-reactor storage on worker and public exposures is essential for making an informed decision on health risks associated with the disposal concept. Such an analysis should include both normal operating conditions and accident scenarios. [Comment 1981, Source Document ph3pub216, Page 04]

Energy Probe (Rubin)

The timing of "disposal" - especially if it is permanent and irretrievable - is clearly a key variable affecting safety, and the subject of much disagreement in phase 1 and phase 2 of this hearing. Yet AECL has not seriously attempted to model its impact or optimize the decision ... Here are some facts that must be considered in doing that optimization ... [Comment 2083, Source Document ph2tec024, Page 7]

Page 38 indicates (and we agree) that there is a trend toward more protective safety standards (either in general or for radioactive contamination in particular), as well as a trend for "new biological information" to increase the risk factors for radiation. Accordingly, there may well be a clear benefit to future populations from delaying the disposal of these radioactive wastes, until standards have become more protective. AECL should be directed to connect these two issues [Comment 2063, Source Document pub014r, Page 8]

Mouvement Vert - Mauricie

Nuclear waste could just as easily be transported to a permanent repository when the power plant is being decommissioned or dismantled, when its radioactivity would be lower.... Such a strategy would make it possible to avoid multiplication of sites and institutions. The MVM would like AECL to study the possibility of storing spent fuel on the power plant sites until they are decommissioned, and discuss the advantages and drawbacks of this approach as opposed to the geological disposal of 10-year-cooled fuel. [Comment 1480, Source Document pub024, Page 13, Section 2.2.1]

OPG RESPONSE

In 2002, OPG and the other nuclear energy corporations in Canada formed the Nuclear Waste Management Organisation (NWMO). The NWMO was established in accordance with the federal Nuclear Fuel Waste Act to investigate approaches for long-term management of Canada's used nuclear fuel. The NWMO must submit the study within 3 years (i.e., by November 2005) and the federal government will then decide on the preferred approach for long-term management of used nuclear fuel waste in Canada. These approaches include, but are not limited to, on-site storage at reactor sites, centralised storage either above or below ground, and disposal on the Canadian Shield.

OPG has conducted studies on the timing of emplacing used fuel in a geological repository. The reference geologic repository concept would have 30-year old used fuel (Russell and Simmons 2003).

Studies of extended storage have also been conducted by OPG and the other waste owners to support the NWMO's assessment of the approaches. The NWMO is presently assessing these options.

The Canadian Nuclear Safety Commission sets radiation protection standards for the operation of nuclear facilities. While there has been a trend towards lower dose or risk limits set by national authorities over the past few decades, there is no particular reason to expect this as logically continuing to lower values in the future - new information (e.g., on the hormesis effect) could suggest present values are conservative. Also, the current CNSC dose and risk limits are only a fraction of the natural background radiation levels experienced by all living organisms, and the predicted dose and risk levels from preclosure and postclosure safety assessments are a small fraction of the regulatory limits.

References:

Russell, S.B. and G.R. Simmons. 2003. Engineered barrier systems for a deep geologic repository in Canada. Proc. 10th International High-Level Radioactive Waste Management Conference, Las Vegas, USA.

2.02 Project Management - Timing of Design Decisions

PARTICIPANT COMMENTS

Canadian Geotechnical Society

the final repository may be dictated by political, social or voluntary acceptance reasons. In such a case, the site may not necessarily have the "best rock conditions", therefore, the engineered barriers and especially the grouting and sealing programs would have to be specifically designed to compensate for less than adequate rock conditions. These can be best resolved once specific candidate sites are being identified and actual geological conditions are beginning to be understood. [Comment 1104, Source Document pub020, Page 13]

Joint Committee of the Canadian Academy of Engineering and the Royal Society of Canada

Since there are options available in most, if not all, of the aspects of the design and construction of the vault system, and the preferable choices may not be determinable until a specific geological site is under consideration, we recommend that decisions on particular design or construction features be not too hastily made. It is most important that the best design for the vault system not be compromised by becoming committed to specific design features at too early a stage. [Comment 1173, Source Document ph2tec010, Page 12, Section H.5]

Northwatch (Richardson)

AECL should also refrain from making major design decisions until intercomparison exercises have been carried out at several sites in different geological terrains and geological environments. [Comment 1525, Source Document ph2pub009, Page 17, Section 4]

People Against Lepreau 2

The EIS is not specific with regard to the materials to be used for storage containers or the designs or dimensions of these containers. Instead, the EIS generally describes containers that could be used. We request that the proponent state exactly what types of containers will be used and provide detailed information on container materials and design. [Comment 1636, Source Document pub018, Page 2]

OPG RESPONSE

The design of the engineered barrier system and deep geologic repository would be optimised based on the characteristics of the specific repository site. The current design options for a deep geologic repository are described in Russell and Simmons (2003).

However, major design choices for the reference concept have been made in order to focus the further development work and assessment work. These decisions are based on thorough reviews of options (e.g., the selection of copper as the corrosion barrier material in the used fuel container, see Maak 1999).

OPG and the other Canadian used fuel owners use Dry Storage Containers for surface storage of used fuel. There are several versions in use, but all are based on a combination of concrete and steel. A summary of these storage container designs is provided in reports available on the NWMO website. More information on the current reference disposal container design is provided in reports available on the NWMO website, and in Russell and Simmons (2003).

References:

Maak, P. 1999. The selection of a corrosion-barrier primary material for used-fuel disposal containers. Ontario Power Generation Report 06819-REP-01200-10020-R00.

Russell, S.B. and G.R. Simmons. 2003. Engineered barrier systems for a deep geologic repository in

Canada. Proc. 10th International High-Level Radioactive Waste Management Conference, Las Vegas, USA.

2.03 Project Management - Timing of Probabilistic Safety Assessment

PARTICIPANT COMMENTS

Northumberland Environmental Protection

The one and only environmental undertaking during PERFORMANCE ASSESSMENT is to ensure the modelling will derive a number within the regulatory limit. Obviously this is quite easy if you are permitted to MODEL BACKWARDS from the regulatory limiting value. To assure this, the implementers must naturally be given the "flexibility" to devise new new modelling as they go (like slippery tracks) to fit the data to the regulatory number....uncertainty around the choice and mismatch of models gives scope for SHIFTING derived quantitative numbers by orders of magnitude. With new choice of assumptions and choice of models, the number for the copper case (with the same data) could easily be increased to fit any regulatory limit.... To argue that the model must be fashioned to fit a specific site defeats the whole object of a model that achieves a degree of confidence only from the fact that IT IS MODELLED AHEAD OF TIME, IS ESTABLISED AND APPROVED INDEPENDENTLY AHEAD OF TIME, and then is used afterwards to interpret an effect from specific sites, where the site specific data is fed in. [Comment 1506, Source Document cs028, Page 2]

Scientific Review Group

the probabilistic safety assessment of the entire disposal system should be deferred until the site evaluation stage, when actual, site-specific field and laboratory measurements can be used to develop and apply a realistic geosphere model, properly linked with an equally realistic vault model to allow feedback between the two. A specific site will also provide actual data on the surface environment (topography, watercourses, soils, biota) that will allow the development of a more representative and relevant biosphere model. [Comment 546, Source Document tec004a, Page 19, Section 3]

OPG RESPONSE

First, it should be stated that "modelling backwards" from a desired result would go against the professional and personal standards held by members of the safety assessment groups. Furthermore, there is enough consensus within the technical community regarding appropriate models and values for key processes, that choice of models and assumptions to "fix" the results would not pass peer review.

Second, model development should occur in order to incorporate new results from ongoing research in Canada and elsewhere and to take advantage of improvements in computers. However, we do recognize that models that have been well-established are more convincing. We therefore approach the modelling from a continuous improvement viewpoint, so that most of the models are described and tested ahead of when they would be used in a siting application.

With respect to probabilistic safety assessments of conceptual site models, we think these can be useful in advance of a specific site. Such analyses can explore generic design or siting issues and test the safety assessment tools. Recent probabilistic analysis with the Third Case Study conceptual design has been useful in identifying the importance of the uranium solubility model, for example (Gierszewski et al., in preparation). Of course, the level of effort should be commensurate with the expected usefulness of the results. And the probabilistic analysis would be carried out at the site evaluation stage with site specific data.

Reference:

Gierszewski, P. et al. Third Case Study postclosure safety assessment. Ontario Power Generation Report 06819-REP-01200-10109-R00 (in preparation).

2.04 Project Management - Integration

PARTICIPANT COMMENTS

Atomic Energy Control Board

the EIS does not adequately address how different social perspectives might impact on the technical work and vice-versa. [Comment 552, Source Document gov002, Page 06, Section 5]

it fails to recognize adequately the possibility that site selection may involve substantial interaction between technical and social communities. [Comment 553, Source Document gov002, Page 06, Section 5]

it has not adequately considered the possibility that social processes might dominate in the early site screening stages, and it has not demonstrated that this contingency can be adequately addressed with the current technical characterization and assessment tools. [Comment 554, Source Document gov002, Page 06, Section 5]

Canadian Geoscience Council

We are concerned that ongoing management decisions will have to cost-effectively optimize data collection, and we urge that scientific, economic and political factors be effectively balanced. [Comment 1044, Source Document tec002, Page 16, Section 3.2.3]

Within the nuclear disposal program, interdisciplinary interfaces need to be strengthened. [Comment 1024, Source Document tec002, Page iii, Section ES]

Joint Committee of the Canadian Academy of Engineering and the Royal Society of Canada

We restate our opinion that social considerations will probably be of greater relevance than technical concerns, and our emphasis on the need for full integration of technical and social aspects. While such integration is outlined in the EIS through the five implementation principles, which we support, we reinforce our view that integration must be clearly evident and continuously developed and assessed throughout all stages of implementation. This view collects and reflects a constant theme in concerns voiced by many other intervenors in these hearings. [Comment 1189, Source Document ph3tec001, Page 5]

OPG RESPONSE

In 2002, OPG and the other nuclear energy corporations in Canada formed the Nuclear Waste Management Organisation (NWMO). The NWMO was established in accordance with the federal Nuclear Fuel Waste Act to investigate approaches for long-term management of Canada's used nuclear fuel. The study is to include public consultation. The description of each approach will also include a program for public consultation. The NWMO must submit the study within 3 years (i.e., by November 2005) and the federal government will then decide on the preferred approach for long-term management of used nuclear fuel waste in Canada. NWMO has been consulting widely with the public and stakeholder groups.

OPG recognises the importance of social processes and public input. The five principles outlined by AECL provide a basis for a siting process; further details on this aspect were described in the Panel report. OPG agrees with these principles. However, the need for a siting process, and the details of what that process will consist of, are not determined at present.

Throughout the siting and site characterisation processes and all stages of site development, next steps will have to be regularly re-evaluated in the light of new knowledge, new information, and social and political inputs. Safety will be of primary importance, and will have to be demonstrated to the independent regulator. In addition, OPG is involving universities and other institutions in the deep

geologic repository technical program. Technical advisory groups are another means of obtaining broader scientific consensus on important issues.

As required by the Nuclear Fuel Waste Act, the NWMO has an advisory council representing a wide range of stakeholders. It is anticipated that other groups such as a Community Liaison group, and special interest groups, would also be involved in an ongoing program and would contribute to obtaining a technically and socially acceptable result.

2.05.01 Project Management - Multiple Barriers - Reliance

PARTICIPANT COMMENTS

Chemical Institute of Canada

I can't help feel that there is some moral requirement for us to attempt to confine a man-made waste product for as long as possible within barriers of our own design. Moreover, the extrapolation of corrosion behaviour over long periods is on a firmer scientific foundation than the extrapolated behaviour of site-specific hydrogeologic systems. [Comment 1119, Source Document tec005, Page 10, Section I.i.C]

Joint Committee of the Canadian Academy of Engineering and the Royal Society of Canada

Uncertainty associated with geological barriers are likely to be greater than uncertainties associated with engineered barriers but, by careful site selection, uncertainty can be reduced to an acceptable level. [Comment 1159, Source Document ph2tec007, Page 06]

Northwatch and Campaign for Nuclear Phaseout (Kreusch, Neumann, and Gruppe Ekologie)

AECL, in their search for a disposal site, should find a reasonable geological barrier. Only a very good natural barrier (low permeability rock and suitable hydrochemical conditions) combined with the best artificial barrier can minimize the resulting long term dose rate (this is necessary according to the ALARA principle). Furthermore, a powerful natural barrier can compensate, at least partly, the possible failure of an artifical barrier. [Comment 1579, Source Document ph2tec044, Page 07, Section 2.3]

Scientific Review Group

the evidence presented points to a total dependence of the AECL concept on an intact WEZ. [Comment 436, Source Document tec004, Page 078, Section 6.6.2]

OPG RESPONSE

Designs for the disposal of used fuel are based on the multi-barrier concept to ensure the required isolation. Overall system safety depends on a series of barriers, and performance remains robust even if one barrier fails to function as expected. However, the design intent would be to confine the radionuclides from the used fuel within the engineered barriers, in particular the used-fuel container, for as long as possible. As part of the maintenance of the disposal technical program, OPG has carried out work on container materials, design and emplacement with the aim that the container will provide containment for at least 100 000 years (Russell and Simmons 2003). For the purposes of safety assessment, and to demonstrate the robustness of the overall system, calculations are carried out using a failure rate based on conservative expectations for similar items.

Within the multi-barrier system, barriers may be natural or engineered features. The geosphere has an important role to play in isolating the used fuel from the human environment and providing a stable environment for the components of the disposal system. At a suitable site, it also provides retardation, sorption, and dilution of radionuclides released from the engineered barriers, contributing to overall safety. A combination of both well-designed, long-lived engineered barriers, and a good geological setting, is desirable.

Safety assessments in the current stage of the program are using reference geospheres to study further the performance of the engineered barriers. At a site-specific stage, assessments would look at overall system performance as site data became available.

OPG follows and contributes to international development of multi-barrier philosophy.

Reference:

Russell, S.B. and G.R. Simmons. 2003. Engineered barrier systems for a deep geologic repository in Canada. Proc. 10th International High-Level Radioactive Waste Management Conference, Las Vegas, USA.

2.05.02 Project Management - Multiple Barriers - Redundancy PARTICIPANT COMMENTS

Atomic Energy Control Board

AECL has not shown that the multi-barrier concept, as represented by their reference design, contains sufficient redundancies. It appears that the loss of one barrier would compromise the safety of the disposal system, and it appears that the loss of another barrier would, at a minimum, significantly impact on safety. [Comment 561, Source Document gov002, Page 16, Section A.3]

two barriers account for most of the containment and attenuation of the contaminants released from the fuel. The predicted safety of the disposal system is largely dependent on the impermeability of the waste exclusion zone of sparsely fractured rock and the high porosity of the emplacement room backfill. AECB staff questions whether the performance predicted for either of these barriers in the AECL reference design is attainable, and it appears that a loss of effectiveness of either barrier would have significant consequences. [Comment 562, Source Document gov002, Page 16, Section A.3]

Joint Committee of the Canadian Academy of Engineering and the Royal Society of Canada

the Committee encourages the executing agency not to rule out the possibility of additional barriers such as, for example, a second container shell, if they should be considered technically viable, effective, and advisable. [Comment 1167, Source Document ph2tec010, Page 07, Section D.5]

Northwatch (Willis)

AECL may have overlooked that the multi-barrier' concept must apply to each and every radionuclide, because each has specific physical, chemical, and radiological properties. It is not enough to design multiple barriers for a generic fuel waste because this may in reality amount to only single barriers for certain radionuclides. [Comment 1567, Source Document ph3pub096a, Page 10, Section 5]

OPG RESPONSE

The comments were based on the AECL EIS concept, where the sparsely-fractured rock was a key barrier. The subsequent AECL Second Case Study (1996) provides a different perspective on barrier redundancy. In this case, the geosphere was chosen to be less robust, while the vault design was made more robust (more durable container, in-room geometry). In this SCS case, the AECB risk criterion was also met. Furthermore, other barriers not considered in either study include Zircaloy cladding, matrix diffusion in the rock, and the stability of dense saline fluids at depth.

The range of possible barriers provides confidence that sufficient redundancy can be achieved through appropriate design and siting. Future safety assessments will continue to assess the redundancy of the barriers in the context of specific case studies, in part through explicit 'what-if' scenarios. For example, the OPG Third Case Study explicitly considered defective barriers cases to test the redundancy of the system (Gierszewski et al., in preparation).

Reference:

Gierszewski, P. et al. Third Case Study postclosure safety assessment. Ontario Power Generation Report 06819-REP-01200-10109-R00 (in preparation).

2.05.03 Project Management - Multiple Barriers - Performance Criteria PARTICIPANT COMMENTS

Atomic Energy Control Board

A minimum 500 year [container] lifetime will provide containment for the short-lived fission products, but it will not provide containment for the longer-lived fission products, activation products and actinides that the postclosure assessment indicates are the major long-term contributors to human dose: 129I, 36C1, 14C and 99Tc (Postclosure PRD). [Comment 607, Source Document gov002, Page 43, Section C.1.3(i)]

A longer-lived container would compensate for many of the performance uncertainties associated with the other barriers.... A container that would not release any radionuclides before the next glaciation (anticipated to begin 10,000 to 25,000 years from now) would offer increased long-term safety because human habitations near the repository are unlikely to be viable once the northern portion of North America is into the next glacial cycle. [Comment 612, Source Document gov002, Page 45, Section C.1.3(i)]

Saskatchewan Environmental Society

the disposal plan must be designed around a time frame that truly protects future generations. Future generations should be assured that high level nuclear waste will be completely isolated from the environment for a period of at least 10,000 years.... [The] 500 year minimum target spelled out in the AECL concept is unacceptable [Comment 1704, Source Document ph3pub006, Page 2]

Scientific Review Group

it would be prudent to isolate the fuel waste from all of the biosphere including the subsurface biosphere given that well established relationships between microorganisms and various fouling and corrosion processes. [Comment 302, Source Document tec004, Page 241, Section I-1.1]

OPG RESPONSE

Preliminary system requirements under development as part of OPG's disposal technical program contain a requirement for the container to remain intact for 100 000 years (see also 2.05.01). It is also planned to carry out safety assessment for time periods up until the time of the maximum dose, while recognising the increasingly qualitative nature of these estimates. The question of biospheres to be used in such assessments is still a matter for discussion, however, it would likely be conservative, for individual dose and risk, to use the same critical groups as used for nearer-term analyses.

Microbially induced corrosion is the subject of research both in OPG's program and in other programs and will be considered in safety assessments.

2.06 Project Management - Observational Approach

PARTICIPANT COMMENTS

Atomic Energy Control Board

The relationship between assessment methods, engineering design choices and site characteristics is very important and this is not adequately addressed in the EIS. [Comment 551, Source Document gov002, Page 05, Section 3]

There is little discussion about the processes required to ensure that new information obtained during siting and construction is properly integrated into the design and safety assessment processes. It is not sufficient to just incorporate new data into the site models. Existing models and beliefs about the suitability of the site need to be continually tested against the new information, and based on those test it may be necessary to drastically change the conceptualization of the site or declare the site unsuitable for nuclear fuel waste disposal [Comment 566, Source Document gov002, Page 20, Section A.5.3]

There was little integration and feedback between performance assessment and engineering design demonstrated in the case study, and this reflects poorly on the ability to implement the concept.... there is no indication in the EIS of the feedback processes that are claimed to be "one strength of the approach" ... The performance assessment presented to demonstrate the tools does not appear to feed back into the design process at any step. No procedures to perform iterations on the container design, on the vault design, or on the derivation of siting criteria based on up-dated performance assessments are presented. Nor are procedures presented for incorporating new information in the performance assessment by means of re-analysis of the scenarios, re-evaluation of the appropriateness of the models and their underlying assumptions and limitations, or revision of the parameter input distributions. [Comment 572, Source Document gov002, Page 25, Section A.6.7]

No procedures to perform iterations on the container design, on the vault design, or on derivation of siting criteria based on up-dated performance assessments are presented. Nor are procedures presented for incorporating new information in the performance assessment by means of re-analysis of the scenarios, re-evaluation of the appropriateness of the models and their underlying assumptions and limitations or revision of the parameter input distributions. [Comment 701, Source Document gov002, Page 82, Section E.3.3]

siting the facility's shafts and tunnels (Preclosure PRD, p. 2-22) would require a closed feedback loop whereby the site characterization is continually used to modify the vault design and its performance assessment. Such a mechanism is not mentioned in the discussions. [Comment 702, Source Document gov002, Page 82, Section E.3.3]

Canadian Geoscience Council

A "design (and improve the design) as you go" strategy that includes continuous input from the geologists is more realistic and better suited for such a long-term project.... An adaptive, design-asone-goes strategy is much more likely to be secure and cost-effective than is forced conformance to a preordained physical plan approved at the completion of surface studies. [Comment 1031, Source Document tec002, Page 10, Section 2.2.1]

Health Canada

Sections 6 and 7 ... do not specifically address how the implementing Organisation will acquire and incorporate new scientific, technical or economic information, or how changes in the design and implementation of the concept will be accommodated [Comment 942, Source Document gov006, Page 12]

Joint Committee of the Canadian Academy of Engineering and the Royal Society of Canada

AECL has specified a degree of flexibility in the construction stage which will allow for changes of procedure if unforeseen events are encountered. Given the inherent variability of the geosphere and the difficulties of predicting non-uniformities and fractures, the principles of multiple barriers and of maintaining flexibility during vault construction are essential. [Comment 1154, Source Document ph2tec007, Page 02]

We urged flexibility at all stages of the vault system design to allow adaptation to actual site characteristics [Comment 1180, Source Document ph3tec001, Page 3]

AECL has specified a degree of flexibility in the construction stage which will allow for changes of procedure if unforeseen events are encountered. Given the inherent variability of rocks, maintaining flexibility is very important. [Comment 1152, Source Document tec003, Page w11, Section 9.c]

Natural Resources Canada

it is stated that postclosure assessment would play an integral role in all stages of the implementation of a disposal system. However, the feedback mechanisms and criteria for decision making have not been identified. It is not stated how decisions will be made to select the best options for design criteria. Is the objective of the assessment to demonstrate that the annual does estimates (ADEs) meet AECB requirements, or is the objective to obtain optimum safety margins within certain cost constraints? [Comment 771, Source Document ph2gov001, Page pos2]

OECD/NEA Review Group

Co-ordination and integration of performance assessment, design and site investigation are essential at the site characterisations stage in order to allow properly founded operational decisions (e.g. shaft position, repository depth and orientation, etc). This does not necessarily imply the use of detailed, full system analyses. [Comment 1247, Source Document tec001, Page 17, Section 5.1]

The Group is strongly in favour of an approach to the overall Program which would ensure the closest integration of repository design, performance assessment and site characterisations. [Comment 1253, Source Document tec001, Page 18, Section 5.2]

Scientific Review Group

The observational construction method ... its success relies on the judgement and the rapid execution of decisions made by the experienced engineer. The very nature of this project (the tendency to seek consensus) runs against the elements of this method and its application requires further careful consideration. [Comment 69, Source Document tec004, Page 133, Section C-1.1]

OPG RESPONSE

OPG believes that siting, design, and safety assessment are complementary processes requiring integration and considerable iteration to arrive at an optimum repository system during facility design and siting and to evolve the repository facility design during construction and operations in response to new information, regulations and technology developments. In preparing the EIS for geologic isolation of used fuel, AECL went through a number of iterations in repository system design and safety assessment methodology using the Whiteshell Research Area as the reference "site" (e.g., ICAD1, ICAD2, EIS). However, the need for clearer and more traceable feedback methods among siting, safety assessment and engineering design has been identified and OPG is taking steps to address this need by developing methods and tools to more effectively integrate these processes. These methods will be first required during a site investigation phase of the deep geologic repository program. The Third Case Study (Gierszewski et al., in preparation) incorporates some of the required factors in the choice of position of the reference vault within a hypothetical realistic geological setting.

OPG fully expects that the design for a deep geologic repository will have multiple barriers and will accommodate the site features, as they become known during the site characterisation period, and during facility construction and operation. Maintaining controlled flexibility during the preclosure phase of a repository facility and during the closure operations is considered to be important. This controlled flexibility will be provided by management systems that will recognise this need and will include organizational structure, formalised engineering systems and decision-making processes. The details of these could only reasonably be developed when the deep geologic repository project was being initiated by the Nuclear Waste Management of used nuclear fuel waste. However, there is a recognised approach to long-term management of used nuclear fuel waste. However, there is a recognised approach to applying controlled flexibility to geotechnical projects, the Observational Method (Peck 1969). The elements of this Method would be integrated into the management systems established for implementing a geologic repository facility.

AECL's postclosure safety assessments throughout the 1980's and 1990's have proved to be a useful tool to provide feedback to engineering design during the concept development phase of the program. For a recent example, see Da Silva (2001), where postclosure safety assessment was used to evaluate different container designs and capacities.

Reference:

Da Silva, M. 2001. Scoping analyses of radionuclide isolation capabilities of container alternatives for a deep geologic repository, Ontario Power Generation Report 06819-REP-01300-10023-R00.

Gierszewski, P. et al. Third Case Study postclosure safety assessment. Ontario Power Generation Report 06819-REP-01200-10109-R00 (in preparation).

Peck, R.B. 1969. Advantages and limitations of the Observational Method in applied soil mechanics. Ninth Rankine Lecture. Geotechnique 19, 171-187.

2.07 Project Management - Technical Review

PARTICIPANT COMMENTS

Campaign for Nuclear Phaseout

The EIS relies extensively on documents produced by AECL as references. A majority of the documents cited in the EIS are AECL produced. How many of these documents cited have been submitted to proper review - that is, to a scientific assessment conducted by persons who do not derive income from AECL related activities? [Comment 1826, Source Document pub027, Page 36, Section III.H]

include critiques of the concept from independent scientific sources. [Comment 1827, Source Document pub027, Page 36, Section III.H]

Canadian Coalition for Nuclear Responsibility (Regroupement pour la surveillance du nucléaire)

It is also particularly difficult to have confidence in the quality of references which have not been subjected to independent peer review. [Comment 1877, Source Document pub049, Page 11]

Canadian Geoscience Council

We urge continuous effort to bring together the full spectrum of geological and engineering disciplines to provide opportunities for interactions, and broad peer review of all aspects of the work. [Comment 1077, Source Document tec002, Page 28, Section 5.1]

Some of the material [in the EIS] is based on papers in peer-reviewed journals, some of the work done by AECL has been submitted to peer-review, but much is in the grey literature of AECL Reports. We recommend that as much material as possible be submitted for peer review in meetings and in publication. [Comment 1078, Source Document tec002, Page 28, Section 5.1]

the committee recommends that: ... a rigorous, peer-reviewed and interdisciplinary process involving geoscientists from a wide range of disciplines be implemented. The task of finding sites is enormous and new discoveries in geoscience--such as the rates of environmental change and the effects of nonlinear (~chaotic) processes--in modeling long-range geoscience processes will require a wide range of on-going geoscience expertise in the disposal project. [Comment 1023, Source Document tec002, Page iii, Section ES]

Canadian Geotechnical Society

the CGS strongly believes that there should be ongoing technical dialogue and debate on key issues to ensure that the most suitable decisions are made based on Canadian geological, geographical and social conditions. [Comment 1088, Source Document pub020, Page 07]

Concerned Citizens of Manitoba

In many cases, AECL makes sole reference to its own documents as evidence for statements regarding technical feasibility, levels of risk, etc. This method of circular argument and relying on technical and scientific studies which are not subject to peer review does little to inspire confidence in the accuracy of the claims. [Comment 1947, Source Document pub034, Page 2]

Joint Committee of the Canadian Academy of Engineering and the Royal Society of Canada

The Committee ... recommends that provision be made in the organization of the agency executing the project for review panels of qualified independent experts, and that the terms of their involvement be such that their participation is both effective and timely. [Comment 1166, Source Document ph2tec010, Page 06, Section C.7]

provision must be made for independent external reviews on an ongoing basis. Part of our concern here is the need to retain for this purpose the cadre of expertise acquired in the period leading to the implementation decision.... provision should be made for review panels of independent experts for the ongoing design, construction and closure phases. Post closure monitoring and the decision concerning final sealing of the vaults should be subject to review, also, by panels of experts and even the public. [Comment 1175, Source Document ph3pub034, Page 1]

The commendable policy of presenting the results in peer-reviewed journals should continue as one of the most effective assurances of research quality. [Comment 1178, Source Document ph3tec001, Page 3]

Provision must also be made for a review panel, or panels, of independent experts to evaluate site selection and all phases of transportation, vault design, construction, operation and closure, continuing into post-closure monitoring. The scope and membership of the advisory bodies must span the full breadth of social, ethical, scientific and technical issues that the disposal program encompasses and must report publicly. [Comment 1179, Source Document ph3tec001, Page 3]

we urge the consideration of suitable examples in Canada and elsewhere of review, oversight or advisory panels of experts as models for the ongoing review of the implementation process which we have asserted previously to be essential for credibility. Such panels chosen independently and reporting publically on a regular basis, can contribute to public understanding and confidence as the implementation process moves, step by step, through its various stages. [Comment 1190, Source Document ph3tec001, Page 6]

positions must be supported by definite evidence, backed up, where possible, by outside expertise, and not presented as opinions of the proponents.... it was not clear to what extent the research and studies of the proponents have been vetted by independent expertise. In order to have consensus and support of the "public", it would seem to be important to have independent judgments on important issues, and these expert opinions should be fully documented. [Comment 1139, Source Document tec003, Page g1]

certain critical values are required for calculations. It is important that these critical values be clearly identified and justified through independent expert opinion or studies. [Comment 1140, Source Document tec003, Page g2]

Northumberland Environmental Protection

It is hard for the general public to grasp that computer simulation might not entail SCIENTIFIC VALIDATION and may be no more than a common deceit. The mathematical computations and graphs LOOK THE SAME. Here is where independent scientific advisors are needed. [Comment 1508, Source Document cs028, Page 3]

Northwatch

AECL relies on and uses as references their own in-house documents, which have not been refereed or peer reviewed, or at least there is no distinction between those that have been and those which have not; [Comment 1352, Source Document pub046, Page 04, Section c.1]

Nuclear Awareness Project

only peer reviewed reports should be used to substantiate any assumptions or conclusions [Comment 1608, Source Document pub035, Page 6, Section D]

OECD/NEA Review Group

The use of expert judgement is an unavoidable part of the process of data interpretation and application within a safety assessment.... An appropriate range of peer views, not only by in-house experts, should be sought in order to minimise potential biases. The expertise of the data providers should be well established. The Group felt that the way in which this was done in the EIS was not clear, as the documentation does not discuss it. Future exercises should report on the process specifically. [Comment 1237, Source Document tec001, Page 15, Section 4.4]

Scientific Review Group

For projects of this magnitude and complexity, a Technical Review Board with arbitration authority will be required (a) to interpret independently the results of performance monitoring, (b) to oversee the quality assurance program, and (c) to resolve disputes between different parties. This is an important component of project management, particularly for the contracting out method (R-Facility 1994: pp.24-27). [Comment 83, Source Document tec004, Page 137, Section C-2.1.7]

United Church of Canada

A review group of ecologists, biologists and ethicists should be assembled to evaluate the assumptions, method, models and conclusions on potential impacts on biota. [Comment 1746, Source Document phpub124, Page 3-21, Section 3]

OPG RESPONSE

In work since the hearings, OPG is encouraging involvement in the technical program of a wider range of institutions, particularly with the universities. Such wider involvement encourages the representation of different views, and leads to interaction between different groups and greater awareness in the program of new developments. For example, OPG is funding a Chair in Nuclear Waste Disposal Chemistry at the University of Western Ontario, and has worked co-operatively on projects with the Geological Survey of Canada. If the deep geologic repository program moves to an implementation stage, the involvement of specialist technical advisory groups providing review in key areas would be looked at. An example of this approach is the Moderately Fractured Rock Experiment working group.

OPG has Technical Exchange Agreements with SKB and Posiva, which include exchange of all technical reports and other co-operative efforts. OPG is involved in international programs with the OECD (NEA) and with the European Community.

The value of peer review via submission of papers to journals is recognised, and is encouraged within the OPG program. OPG's internal quality assurance requirements for its reports on the deep geologic repository technology program also require that these reports be peer reviewed.

If the deep geologic repository program goes forward, the program will look other forms of review, including:

- free and easy availability of all reports of scientific and technical work
- publication of annual reports with wide dissemination
- periodic review by regulatory agencies (rather than only when a license application is made)
- presentation of papers at local, regional, national and international fora such as meetings of branches of professional societies and conferences.
- participation in international technical co-operation groups
- sponsorship of workshops, typically at universities, and encouraging attendance by key

workers in particular fields

- organisation of an annual technical seminar at which discussion can take place.

Independent review, in the sense that the reviewer is not directly funded by the program, might be done through an external organisation such as the Royal Society. Such a panel could be set up at key points in the program. In the area of postclosure monitoring and repository closure, community and government involvement would be expected.

The Advisory Council required as part of the NWMO's organisation is not primarily a technical advisory committee; rather it is a forum for bringing together viewpoints from a broad range of interested parties. The relationship between the advisory council and any technical advisory groups should be examined and optimised. Setting up of any independent Technical Review Board with a dispute resolution role would be a matter for the federal government to decide as part of its response to the NWMO recommendations.

The parameter values derived from site characterization and other studies and used for safety assessment must be traceable. A systematic compilation of such data is needed which documents the basis for selection of values for each parameter, including where expert judgement has been used. OPG presently maintains a version-controlled dataset of parameter values used for safety analyses. This dataset tracks changes and records the origin of the selected values. These are also documented in appropriate reports, as in the Third Case Study (Garisto et al., in preparation).

It is expected that the framework, methodologies and criteria for estimation of effects on non-human biota will be more fully-developed by the time of any future siting stage for a deep geologic repository.

References

Garisto, F., A. D'Andrea, P. Gierszewski and T. Melnyk. Third Case Study - Reference data and codes. Ontario Power Generation Report 06819-REP-01200-10107-R00 (in preparation).

2.08 Project Management - Quality Assurance

PARTICIPANT COMMENTS

Atomic Energy Control Board

The implementation of a formal quality assurance program for research and design work for waste management was not begun until 1990. As a result, much of the research upon which the SYVAC submodels were based was not conducted under the guidance of a quality assurance program. Furthermore, it appears that the program has not been strictly followed since 1990, as it is stated that the program has not been fully applied thus far but it will be in the future (Biosphere PRD, Section 11.7.1). [Comment 659, Source Document gov002, Page 69, Section C.8.1]

Quality assurance programs for implementation of the concept have not been sufficiently developed. Siting quality assurance program descriptions are too vague to provide confidence that a sufficiently systematic siting process could be successfully carried out in the face of strong schedule, financial, and social pressures (Siting PRD, Section 1.2). Quality assurance program descriptions are too general to enable an assessment of whether the QA approach for disposal facility characterization, construction, operation and closure would be sufficient to ensure that the facility would satisfy AECB disposal criteria (Facility PRD, Section 2.2.3). [Comment 667, Source Document gov002, Page 71, Section C.8.6]

OPG RESPONSE

First, it should be noted that the work carried out under the Canadian program has always been conducted so as to be of high quality, regardless of whether there was a formal QA program in place. For example, quality results were achieved through such "good practices" as working with high-calibre research groups; publication of results in conferences and peer-reviewed literature; and cross-checking of models and results with other international groups through cooperative programs.

The models and data used by OPG are consistent with those used internationally in similar studies or applications; that this is true of the program presented during the EIS hearings is confirmed through the conclusions of the international NEA review of the AECL EIS concept. OPG continues to work with international programs to ensure that its results are consistent with international practices. The nature of international activities are summarized, for example, in the OPG Deep Geologic Repository Technology Program Annual Technical Reports (e.g. Gierszewski et al. 2003).

However, it is recognized that formal quality assurance programs provide a high degree of traceability of results and their verification, and therefore leads to improved confidence in these results. Therefore, while continuing the "good-practices" approach noted above, OPG (and AECL) have developed and are applying appropriate standards and procedures. For example, the Deep Geologic Repository Technology Program requires that its contractors work to ISO 9000 standard or equivalent, and to the CSA N286 standard in specific areas. For example, software intended for potential use in postclosure safety assessments is being developed according to the CSA N286.7 standard. The software QA status of these tools have been described by D'Andrea et al (2001).

With respect to a siting quality assurance program, the various international siting projects (e.g. Finland, Sweden, US) could provide a reference for establishing a Canadian siting QA program, if/when it is required. Guidelines may also be available in CNSC guidance documents under preparation.

References:

D'Andrea, A. et al. 2001. Status of Canadian postclosure safety assessment models for a deep geologic repository for used fuel. Proc. Canadian Nuclear Society Annual conference. Toronto, Canada.

Gierszewski, P. et al. 2003. Deep geologic repository technology program - Annual report 2002. Ontario Power Generation Report 06819-REP-01200-10100-R00.

2.09 Project Management - Construction Management

PARTICIPANT COMMENTS

Scientific Review Group

It is not clear whether construction will be undertaken by contractor or directly by the Implementing Organization (R-Facility 1994: p.21). The organization structure, division of responsibility, method of project implementation, and quality assurance would be very different between these two approaches. [Comment 82, Source Document tec004, Page 137, Section C-2.1.7]

OPG RESPONSE

The Nuclear Fuel Waste Act indicates that the Nuclear Waste Management Organisation (NWMO) would be responsible for the overall management and funding of the geologic repository facility. Currently, OPG assumes that the construction of the facility, decommissioning and closure of the facility would be undertaken by a contractor(s). The operation of the facility, and construction operations during the period of container emplacement, would be undertaken either directly by the NWMO, by a contractor(s), or by a combination of the two depending on which provided the most flexibility.

It is expected that the level of quality assurance associated with the construction, operation, decommissioning and closure of the geologic repository facility would be the same regardless of whether the NWMO or a contractor carried out the actual the work. However, the details of the management systems and the applications of quality assurance and control would be developed for the specific mix of contractors and NWMO operations at each stage during the repository facility project.

2.10 Project Management - Cost/Benefit

PARTICIPANT COMMENTS

Environment Canada

The magnitude of the overestimate of the dose and concentration should be quantified. Overly conservative results could lead to additional and unnecessary engineering requirements, which would significantly increase the cost of the facility. [Comment 885, Source Document gov003, Page 31, Section 2.14]

Joint Committee of the Canadian Academy of Engineering and the Royal Society of Canada

the safest cost-benefit solution remains to be resolved.... what cost can be sustained to place the site in the most favourable location? I did not see discussion of the compromises which must be made between cost and site safety. [Comment 1145, Source Document tec003, Page w03, Section 4]

National Action Committee on the Status of Women

The EIS also does not provide any historical context of what the costs and benefits of spending on capital intensive, job poor, toxic industries such as the nuclear industry have been, particularly with respect to impacts on government spending on funding of social infrastructure and programs and health care desperately needed by women.... In order to fully judge the social costs as required by the Guidelines [Section 7.9] of the proposed concept, the cost of the project in terms of opportunity costs and the ability of the economy to service debt must be evaluated. [Comment 1314, Source Document pub026, Page 62, Section 7.12.1]

Northwatch (Lloyd)

Deficiencies Which Emerged or Remain Outstanding After Discussion in the Phase II Tehncial Hearing Sessions ...

-comparative discussion of AECL approach to optimization [Comment 1535, Source Document ph2tec045, Page 22]

Nuclear Awareness Project

[Do a] cost/benefit analysis of different disposal options, including a more sturdy container, deeper vault, etc. [Comment 1610, Source Document pub035, Page 8, Section E]

Robertson, J.A.L.

There is in the EIS no adequate recognition of the need for economy. Throughout, there is repeated reference to safety being an overriding criterion, without regard to the effects that devoting \$10 billion to a non-productive enterprise would have on the national economy.... Cost-effectiveness means ensuring that the proposed repository be adequately safe, i.e., roughly as safe as other hazardous facilities, but not too safe. To gain public acceptance for the concept it may be necessary to provide a greater level of safety for the disposal of nuclear wastes than for other activities. However, the public should be fully aware of how much extra is being spent to provide this assurance, and what is being lost because the funds are not available for greater safety elsewhere. [Comment 1448, Source Document phpub004, Page 04]

The present generation should proceed to site selection and construction of a repository, and should emplace waste-containing canisters in the repository as proposed in the EIS except for the back-filling and sealing of panels and disposal rooms. The technology for back-filling and sealing should be demonstrated and a supply of necessary materials stock-piled.... What is needed now is a rough estimate of how much extra this option would cost, to determine if this modified concept is worth pursuing. [Comment 1460, Source Document phpub004, Page 33]

Scientific Review Group

costing analyses for alternate designs would also be desirable. [Comment 85, Source Document tec004, Page 138, Section C-2.1.8]

OPG RESPONSE

Safety assessment and performance assessment models are used to provide an indication of the evolution of the geologic repository system and an estimate of the potential impact on humans and the natural environment for a variety of scenarios. The assessment models, assumptions and input data for these scenarios are being designed by OPG to include both realistic and conservative cases. OPG believes that a wide-ranging and balanced approach to safety and performance assessment is required and intends to use these approaches when considering the implications on repository facility engineering and costs. This balanced approach will provide an estimate of the "magnitude of the overestimate of the dose and concentration" associated with any one particular assessment method and data set. While OPG fully supports the multi-barrier approach in the design of the deep geologic repository facility and the development of the safety case, it is aware that there are social, political and regulatory expectations on the safety and acceptability of the repository facility, as well as financial limitations.

Work initiated by OPG, and included in studies submitted to the NWMO by OPG and the other waste owners, incorporates a long-lived copper container that is similar in design to the spend fuel containers in the Swedish and Finnish designs. A revised cost estimate accompanies the updated repository concept and can be used to compare with the previous repository design and cost estimate for the AECL concept submitted in 1994.

2.11 Project Management - Cost

PARTICIPANT COMMENTS

Campaign for Nuclear Phaseout

The cost of monitoring and protecting radioactive waste cannot be adequately predicted. Who is to say that a society 500 or even 100 years from now will have the capacity to deal with stored nuclear waste? [Comment 1783, Source Document pub027, Page 19, Section III.C]

The EIS cost estimates fail to take into account financial liabilities associated with disasters, emergency retrieval of waste, health and safety impacts on workers. [Comment 1814, Source Document pub027, Page 31, Section III.G]

For the \$9 billion in cost estimates that are listed, no sources are provided. According to the Worldwatch institute, an American facility of equivalent size would cost \$36 billion (in 1990 U.S. dollars) to construct (Worldwatch Paper 106, "Nuclear Waste: The Problem That Won't Go Away", December 1991, p.23). The variance between Canadian and U.S. cost estimates needs to be examined. [Comment 1815, Source Document pub027, Page 31, Section III.G]

How were the cost estimates arrived at in the EIS? Have the accounting methodologies and practices employed by AECL to arrive at their estimates been subject to assessment from the Auditor General of Canada or independent sources? [Comment 1816, Source Document pub027, Page 31, Section III.G]

Canadian Coalition for Ecology, Ethics and Religion

The estimated cost of the project is \$13.2 billion ... Many significant costs were omitted. The \$13 billion estimate is likely to be low [Comment 1847, Source Document phpub043, Page 45, Section 18]

Concerned Citizens of Manitoba

The proponents state that the anticipated cost of a facility to contain 10 million bundles of used fuel would cost over 13 billion dollars. While this may be a reasonable estimate at this time, costs are likely to escalate considerably during the siting and construction phases of the proposed project. [Comment 1961, Source Document ph2tec033, Page 4]

The only reference to costs involved in retrieving buried nuclear waste from a post-closure facility is the following: "The resources needed to carry out post-closure retrieval operations are anticipated to be similar in magnitude to the resources required to complete the original disposal." (R-Facility p 321). This does not take into account the possibility that such an operation may have to take place in an emergency situation, as mentioned in the guideline, which would both increase the difficulty of the task and add to the time pressures involved. [Comment 1950, Source Document pub034, Page 4]

Concerned Citizens of Renfrew County

Despite dealing in broad estimates with the cost of the facility, the EIS analysis is incomplete.... How much will the host community for the high-level repository, with its much higher risks, demand in compensation? [Comment 1965, Source Document pub031, Page 2]

Conservation Council of New Brunswick

the \$13 billion figure may well be an underestimate. In the past, AECL capital cost estimates have been underestimated by a factor of three or more. And what about contingency plans? [Comment 1994, Source Document ph3pub162, Page 3]

Ecosystem Approach Group

Estimates of schedule and cost ... are not realistic ... because they exclude the most costly items, as well as the potential for accidents and new technologies. [Comment 2039, Source Document pub033, Page 10]

Energy Probe (Brubaker)

To assure people that, should harm come, they will be able to recover full damages, the implementing organization must maintain adequate insurance coverage on both transport and disposal activities. Furthermore, to ensure that victims will be able to obtain justice long after the implementing organization has ceased doing business, provisions should be made to finance future clean-up and compensation. [Comment 2051, Source Document phpub028, Page 18]

the United States proposes to make annual payments of \$20 million to benefit the community that ultimately hosts a permanent high-level nuclear waste disposal facility. A successful voluntary process could well require greater incentives. Such incentive levels could have a considerable impact on the budget and should be discussed fully and frankly. [Comment 2047, Source Document pub014b, Page 08]

Energy Probe (Rubin)

Appendix A of the EIS volume refers to two sections in that volume as addressing this topic: 3.6.6, "Retrievability", and 5.8.9, "Waste Retrieval" (EIS, pp. 72-72 and p. 199). Neither provides the cost estimates specified in the Guidelines. [Comment 2061, Source Document pub014r, Page 8]

Environment Canada

The estimate of costs is low because of excluded cost elements and because the contingency amounts are too low 19% versus the minimum of 25 to 50% that the engineering literature would indicate). Potentially significant cost exclusions include: impact management, public involvement, extended monitoring, financing, review and approvals, and facility taxes. Potential understatement of costs include ongoing research and training costs.... The calculation of the cost per kwh of the entire concept should be prepared, based on the revised total cost estimate, and based on the most current estimates of total waste fuel volumes, the pattern of future waste generation, and future waste receiving patterns. [Comment 895, Source Document gov003, Page 50, Section 2.27]

The EIS does not contain adequate information to assure the public that reasonable estimates of cost are provided, that all costs have been considered, that the benefits and risks associated with these costs have been evaluated (i.e. cost-benefit analysis) ... Appropriate levels of uncertainty (and sensitivity analyses for those uncertainties) have not been applied to the resulting cost estimates to take into account the uniqueness of the AECL concept and to demonstrate to the public that the concept represents a net benefit to society. [Comment 898, Source Document gov003, Page 66, Section 3]

Hare, Driedger, Jennekens, Rogers, and Shemilt

there are still some socioeconomic issues that may require further attention. These include ... the costing of the proposed measures, which may be inadequate [Comment 1412, Source Document phpub150, Page 5]

Mouvement Vert - Mauricie

the cost of the project should be presented in cents/kWh, and compared with other costs associated with the nuclear cycle: extraction, transportation, research and development, production, interim storage, externalities, etc. [Comment 1483, Source Document pub024, Page 22, Section 2.3.5]
National Action Committee on the Status of Women

AECL estimates in the EIS that the cost of implementing the proposed concept will be \$13 billion dollars (1991 dollars), although it provides no source for this estimate.[EIS p.231] The estimate does not include transport costs, which according to the EIS could add up to \$2 billion to the bill, or financing costs, taxes, or unexpected expenditures as a result of design flaws or accidents. It is not clear whether the costs of compensation or mitigation are included. The EIS also does not provide an estimate of external costs or social costs [Comment 1313, Source Document pub026, Page 61, Section 7.12]

Nuclear Awareness Project

Another important variable excluded from consideration so far is the cost associated with management of the reactor core components, and with other nuclear fuel wastes owned by AECL and other operators of research reactors in Canada. [Comment 1616, Source Document ph3pub138, Page 4]

Scientific Review Group

The cost estimates included in the EIS and R-Preclosure are crude and do not meet conventional professional standards of engineering economics for a project of this magnitude.... No details are provided to judge the accuracy of these estimates, which pertain only to the particular hypothetical reference design. The rates of discounting applied to future cost are not given, and there is no indication if the total cost estimate cited is a mean or most probable value. [Comment 468, Source Document tec004, Page 092, Section 7.3]

Inconsistency in forecasting parameters is also apparent in the data which has been presented, with cost estimates being based upon different initial years (R-Preclosure 1994: Table 2-1, p. 2-12; Tables 7-35 and 7-36, p. 7-95).... A reasoned assessment should have been presented of the uncertainties in costs of the materials, labor and finance markets, based on case histories of engineering projects of similar magnitude. [Comment 128, Source Document tec004, Page 151, Section D-2.2.6]

OPG RESPONSE

OPG believes that the costs of monitoring a deep geologic repository facility for used fuel can be predicted for a defined period of monitoring. While the duration of the extended monitoring period may not be known with precision, the current reference repository concept assumes 30 years of operation and up to 70 years of post-operational monitoring before closure. Nevertheless, it will be up to society and the authorities to decide when to cease monitoring. Therefore, OPG expects that contingencies will be required to accommodate the uncertainty associated with monitoring. The plan for monitoring and the associated costs of monitoring will form part of the overall plan for a geologic repository of used fuel, which will be subject to the normal review and approval process established in Canada.

Any costs associated with retrieval operations will depend on the time of and reasons for a decision to retrieve used-fuel containers. During the preclosure phase, the shafts and access tunnels will remain open and thus the costs of retrieval will be less than during the postclosure phase when these have been decommissioned and sealed. The costs of retrieval operations as described by Acres et al. (1996) are expected to be similar to the costs associated with emplacing the waste. Further work on retrieval technology (e.g. the container retrieval tests underway in Sweden), will provide a basis for improving these cost estimates.

OPG, together with the other waste owners, has submitted to the NWMO studies prepared by an independent consultant which provide an update to the repository concept and cost estimate, with an estimate of contingency. The conceptual design, and the associated schedule and cost estimate are appropriate for the geologic isolation of all nuclear fuel wastes generated in Canada. The revised cost estimate and schedule will be a factor in determining the amount of funds required to manage

Canada's used fuel wastes in the long term. The cost estimates include transportation of used fuel from the storage locations to the final geologic repository.

Costs for management of low and intermediate level waste are accumulated and accounted separately.

The repository concept being developed in the US at Yucca Mountain is significantly different from the Canadian concept, and thus the cost estimates are significantly different. Key differences can be identified and explained. The Canadian cost estimates have been benchmarked against those for the similar repository designs in Sweden and Finland, and will continue to be benchmarked as new information becomes available.

Reference:

Acres International Limited, SENES Consultants Ltd., SPAR Aerospace Ltd and Davey International. 1996. Feasibility of retrieval of nuclear fuel waste from a sealed disposal vault. Atomic Energy of Canada Limited report TR-M-44.

2.12 Project Management - Funding

PARTICIPANT COMMENTS

Campaign for Nuclear Phaseout

It is questionable whether sufficient funds are in fact being set aside. [Comment 1779, Source Document pub027, Page 14, Section III.A]

Canadian Coalition for Ecology, Ethics and Religion

Funding requirements for the proposed project need to be assessed in the context of an overall financial plan for disposal of not just used fuel but of all forms of nuclear waste. [Comment 1861, Source Document ph2pub021, Page 78, Section 12.1]

Canadian Geoscience Council

Site-screening and evaluation is going to be a time-consuming and costly process, and the method proposed will fail if corners are cut in either the funding or time-allotted to site screening. [Comment 1038, Source Document tec002, Page 15, Section 3.2.1]

Canadian Voice of Women for Peace

a trust fund [should] be set up by the waste owners so that monitoring and any necessary actions to prevent or mitigate environmental damages can be carried out by an independent agency. [Comment 1915, Source Document cs023, Page 3]

Concerned Citizens of Manitoba

this concept is an enormously expensive one. Just who is to pay for it? It is apparent that the money that Ontario Hydro, the largest producer of high-level radioactive waste in Canada, has been socking away for waste management is only shown on the books as a liability - it does not really exist. [Comment 1957, Source Document phpub153, Page 6]

Conservation Council of New Brunswick

The nuclear industry has not set aside the estimated \$13 billion necessary to pay for implementing the geologic burial concept, nor has it demonstrated any financial capability to generate this money in time for implementation. [Comment 1993, Source Document ph3pub162, Page 3]

Energy Probe (Rubin)

Funds collected from Ontario Hydro ratepayers for many years for reactor decommissioning and waste disposal ... are unlikely to be available when needed; Those funds (and the much smaller amounts being collected by New Brunswick Power and Hydro Quebec), even if available, will likely be insufficient to do the job. For one thing, the rate of collection is based on Ontario Hydro's goal of amassing ten percent of the total real-dollar cost, by the time the nuclear station shut down at the end of its predicted 40-year lifetime.... We believe this practice is imprudent and recommend that the Panel require the collection of adequate funds by the time the nuclear stations retire.... We believe the assumption of a 40-year life expectancy - especially combined with "straight-line" collection of waste-disposal funds - is imprudent, and recommend that the Panel require that the collection of these funds be "front-end loaded", to minimize the adverse effects of early retirements. [Comment 2077, Source Document phpub041, Page 17]

The need to spend more time and money on research than Ontario Hydro and AECL have anticipated - very likely more time than even the newest Canadian reactor will operate - may require significantly more funds than will be available.... inadequate funding provisions by the owners of Canada's nuclear reactors must not limit or foreclose opportunities to do what is right in the disposal of Canada's nuclear wastes. [Comment 2078, Source Document phpub041, Page 18]

Environment Canada

Assurance that funds will be available, and the structure required to give this assurance, is not addressed in the EIS. Neither does it address the issue of the user-charge scheme or its administration, including the characteristics of an appropriate scheme, and the peculiarities of the Canadian setting with three independent nuclear generating utilities. [Comment 896, Source Document gov003, Page 51, Section 2.27]

Hare, Driedger, Jennekens, Rogers, and Shemilt

costs may exceed existing provisions [Comment 1413, Source Document phpub150, Page 5]

Mouvement Vert - Mauricie

companies involved in nuclear power production already incorporate the cost of disposal into their current rates. However, Ontario Hydro acknowledges that the monies retained have not been specifically set aside for the management of irradiated fuel. Are funds being set aside specifically for disposal? How much does each of the three companies set aside? Is this money readily available? Is a matching government contribution required? [Comment 1484, Source Document pub024, Page 22, Section 2.3.5]

Nuclear Awareness Project

All nuclear reactor operators (utilities, AECL and universities) must establish segregated, guaranteed funds to cover the future cost of all programs associated with nuclear waste management, including research into options other than burial. [Comment 1618, Source Document cs018, Page 1]

The status of all funds allocated by the three nuclear utilities, AECL and other high level nuclear waste owners in Canada needs to be reviewed, and detailed analysis of variables such as early retirement of reactors needs to be carried out. [Comment 1617, Source Document ph3pub138, Page 4]

The situation of all ... high level nuclear waste owners in Canada with respect to their decommissioning and waste burial funds (or lack of funds) should ... be reviewed to ensure that the money for these future costs is secured. [Comment 1613, Source Document phpub123, Page 6]

[Report on] projections for the total amount of money available for nuclear waste disposal under various nuclear power generation scenarios, including a scenario involving early retirement or phaseout of all existing nuclear reactors [Comment 1611, Source Document pub035, Page 8, Section E]

People Against Lepreau 2

The EIS fails to provide information on the current value of the nuclear waste fund in each province. [Comment 1635, Source Document pub018, Page 1]

Planetary Association for Clean Energy

We believe, that cost recovery is not in fact being realistically assimilated in current rates applied to electricity consumers. We also believe that the true cost of the proposed disposal facility is too elevated for the Canadian consumer to accept, and too high for the federal and provincial budgets to absorb. [Comment 1648, Source Document pub029, Page 05]

Robertson, J.A.L.

there is a failure to note that although electricity consumers have been charged for wastes disposal the money exists only on the balance sheets of the utilities and not as real resources. [Comment 1454, Source Document phpub004, Page 17]

Saskatchewan Environmental Society

The new studies provide little information on which to base accurate forecasts of the costs which can reasonably be anticipated, and there is still no provision for the posting of a bond by Ontario Hydro and other producers of nuclear waste. [Comment 1691, Source Document ph2tec039, Page 2]

The cost of implementing the AECL concept will be at least \$13 billion and this may well prove to be an underestimate. To date, no real dollars are in place to implement the concept. The money that has been collected exists on paper only; it is merely an accounting concept. [Comment 1703, Source Document ph3pub006, Page 2]

The current generation must set aside the funds necessary to pay for the costs of high level nuclear waste disposal. These payments should not simply be set aside by way of an accounting procedure but should take the form of a bond that is posted with the Government of Canada and set aside for the use of future generations who will face the difficult challenge of permanently disposing of Canada's high level radioactive waste. [Comment 1679, Source Document phpub094, Page 3]

how [will] the money that has been collected from consumers for nuclear waste disposal ... be protected for that purpose in the event that Ontario Hydro is privatized and in the event that as a result of privatization Ontario Hydro is broken up into smaller companies [Comment 1664, Source Document pub040, Page 05, Section 07]

We wish to seek clarification about whether real dollars are being set aside for nuclear waste disposal or whether money is being set aside for 'accounting purposes only'. [Comment 1665, Source Document pub040, Page 05, Section 08]

Science for Peace (Energy Working Group)

As our group bases much of the need for deep geological disposal on military security, I propose that at least half the costs of geological disposal come from the military budget. [Comment 1719, Source Document ph2pub034, Page 6]

Scientific Review Group

no mechanism has been defined to provide assurance that a guaranteed source of funds will be set aside, or can be effectively managed, to pay for the implementation of nuclear fuel waste disposal over the projected lifetime through to decommissioning. [Comment 84, Source Document tec004, Page 138, Section C-2.1.8]

there is no established plan to assure that financing will actually be available at all, or obtainable at a reasonable rate, to guarantee the financial feasibility of the project. [Comment 129, Source Document tec004, Page 151, Section D-2.2.6]

Transport Canada

We believe that it has not been firmly established that the disposal 'fund' exists in an accessible form and will prove adequate to meet the financial demands of the disposal project proposed, including the financial demands of the transportation operations. [Comment 917, Source Document cs012, Page 3] Ontario Hydro fees, although a demonstrable accounting function on paper, are not accumulated but are, according to Ontario Hydro, reinvested.... In the event that Ontario Hydro could not liquidate these funds for their initial purpose the cost of disposal could fall partially or wholly on the public. The wording on EIS pages 77, immediately following the section on Public Confidence, and 265 give the false impression that the collected fees exist and are accessible... Recommendation #3: That the potential problem area of the availability of funds for disposal, and the manner in which the documentation refers to their existence, be rectified and have this available for presentation Presentations ... should not allude to the existence of a non-existent fund. [Comment 497, Source Document gov001, Page 3]

United Church of Canada

References to collected fees give the false impression that these fees exist and are accessible. That there is no money set aside in a fund should be made clear [Comment 1733, Source Document phpub124, Page 3-06, Section 3]

United Church of Canada (Cambrian Presbytery)

Reference to collected fees gives the false impression that these fees exist and are accessible. That there is no money set aside should be made clear [Comment 1758, Source Document ph3pub041, Page 5]

OPG RESPONSE

The federal Nuclear Fuel Waste Act required nuclear fuel waste producers to establish trust funds to finance the long term management of nuclear fuel waste. These funds are accumulating and may only be used for the purpose of implementing the management approach selected by the Government of Canada, once a construction or operating licence has been issued under the Nuclear Safety and Control Act.

The nuclear utilities in Canada also have provided financial guarantees for coverage of costs for the decommissioning of nuclear facilities, the long-term management of low and intermediate level wastes, and nuclear fuel waste. In Ontario, Ontario Power Generation has met this guarantee through the assets of segregated funds established under the Ontario Nuclear Funds Agreement, the trust fund established under the Nuclear Fuel Waste Act and a provincial guarantee for the balance.

2.13 Project Management - Schedule

PARTICIPANT COMMENTS

Scientific Review Group

Moreover, the experience in large civil engineering projects in Canada and abroad has shown that, for projects of long-time duration, interruptions in funding due to political or economic changes are inevitable. The schedule and planning must make allowance for: (1) delay due to political and economic changes, and (2) provisions for temporary shutdown which may last for years and preservation of partially constructed facilities. [Comment 86, Source Document tec004, Page 138, Section C-2.1.8]

OPG RESPONSE

OPG has prepared a conservative estimate of the schedule for the siting, characterisation, assessment, design and construction of a deep geologic repository for used fuel which takes into account the anticipated time that it takes to reach agreement with communities, prepare and conduct the environmental assessment process, and to obtain approvals and licenses from the authorities for activities associated with the facility.

OPG, together with the other waste owners, has submitted to the NWMO studies prepared by an independent consultant which provide an update the to the repository concept and cost estimate, and which include an updated planned schedule for implementation of the concept, pending a decision by the federal government of the preferred approach to long-term management of nuclear fuel wastes.

2.14 Project Management - Research

PARTICIPANT COMMENTS

Canadian Geotechnical Society

As a main overview conclusion, the CGS believes that the geotechnical aspects now have been studied to the point that further study would be hampered by not knowing the exact geological conditions of the candidate site. [Comment 1089, Source Document pub020, Page 08]

We would see present studies continuing on a pre-site selection basis in parallel with efforts to locate and select a suitable site such that as site specific information on candidate sites becomes available, this can be input to the ongoing studies in a logical, progressive fashion. [Comment 1090, Source Document pub020, Page 08]

Graham, J.

Multi-disciplinary projects of this type need to be carefully planned, controlled, and managed if the data are to be consistent and useful. What is usually required is an incremental approach that can be used for comparing predictions with performance, and developing engineering judgement and confidence. This will require one or two more additional large-scale experiments. [Comment 1414, Source Document ph3pub060, Page 3]

OPG RESPONSE

In general, OPG agrees with the overview conclusion of the Canadian Geotechnical Society that the geotechnical aspects associated with the geologic isolation of used fuel on the Canadian Shield now have been studied to the point that further studies are hampered by not knowing the exact geological conditions of the candidate site.

Ongoing studies can be usefully carried on certain aspects related to site characterisation, visualisation, and resolution of particular issues. Furthermore, OPG believes that it is effective for the Canadian deep geologic repository technology program to continue its development studies in conjunction with other radioactive waste management organisations (e.g., SKB, Sweden; Posiva, Finland) with similar rock types and repository concepts.

2.15 Project Management - Archive

PARTICIPANT COMMENTS

Natural Resources Canada

we recommend that the implementing organization set up an archive to store physical samples and data records obtained from a site evaluation process and make those available for public access at any time during the site evaluation and monitoring stages. This would encourage public confidence through access to samples and records by interest groups, who may then carry out independent research should they wish to do so. [Comment 819, Source Document ph2gov001a, Page 18, Section 2.5.3]

OPG RESPONSE

This looks like a good idea and will be noted. Implementation could begin, at the earliest, at the site identification stage.

2.16 Project Management - Institutional Controls

PARTICIPANT COMMENTS

Action Against Nuclear Waste Committee

We are particularly concerned about the security issue raised if the spent fuel being stored is usable in weapons. Although our country is currently a peaceful democracy, how can we make the assumption that this stability, which is little over 100 years old, will necessarily continue for 500 or 10 000 or 250 000 years? [Comment 1766, Source Document phpub030, Page 1]

Campaign for Nuclear Phaseout

The EIS states that "one way to protect a disposal vault following closure would be to establish a park or wildlife preserve on the site" (AECL EIS, p. 200) How would this "protect" the disposal vault? What would be implications for plant and animal life of radiation from the vault? What would be the ecosystem impacts, were there an attempt to retrieve waste from such a site? [Comment 1787, Source Document pub027, Page 23, Section III.C]

Coalition pour la surveillance du nucléaire (COSUN)

There is absolutely no reason to believe that an underground facility would need any fewer institutional controls than an above-ground one. Given the exponential acceleration of technology, it would be prudent to assume that those, in the future, who want to extract the contents of an underground nuclear burial place, will be able to do so with whatever technologies and for whatever purposes they may have in mind. [Comment 1267, Source Document pub011, Page 05]

Conservation Council of New Brunswick

There is no basis for assuming that future generations will not compromise the integrity of a repository, either wittingly or unwittingly. Large population centers may arise in previously uninhabited areas and penetrate the burial site repeatedly like a pincushion. Archaeologist of the future may be intrigued by the evidence of massive man-made excavations, and dig down to unearth imagined treasures. Future military leaders may go after the plutonium contained in the used nuclear fuel to build an arsenal of nuclear weapons. The assumption that institutional control will not be needed is unacceptable. [Comment 1992, Source Document ph3pub162, Page 3]

Durham Wetlands and Watersheds

More discussion of Permanent Marking of the Nuclear Fuel Waste Facility after closure. [Comment 2010, Source Document pub043, Page 5]

Earth Resources Society of Elliot Lake (Krauss and Dube)

Will the area be highly identifiable and visibly protected forever? [Comment 2024, Source Document pub002, Page 10, Section 6]

Mouvement Vert - Mauricie

Are there current technologies that make it possible to mark a territory for a period of several tens of thousands of years? [Comment 1494, Source Document pub024, Page 33, Section 2.4.6]

Saskatchewan Environmental Society

elaborate on how the vault location might effectively be marked so as to communicate to future generations the risks involved. [Comment 1675, Source Document pub040, Page 11, Section 20]

Science for Peace (Energy Working Group)

the AECL disposal concepts are marked by 'semiotics of absence', i.e. the omission of an attempt to think about communication to future generations. [Comment 1715, Source Document ph2pub034, Page 4]

OPG RESPONSE

Institutional controls are expected to continue far into the future. Two important aspects are:

Maintaining knowledge of the repository, for example via surface markers and records, such as the normal land use and ownership records maintained at the local, provincial and national level, and
Maintaining land use controls, for example setting aside the area as a park. It may be noted that the New Forest in southern Britain has been protected by regulations and has maintained its historic uses for 900 years. In relation to restriction of possible future uses, it may be noted that no radiological impacts are expected in the normal evolution of the repository.

There is as yet no conclusion as to what would be the preferred methods; likely several will be used based in part on consultation with the adjacent communities at the time of site selection and development

Together with permanent marking, safeguards against the use of the fissile material contained in disposed used fuel in weapons is an aspect which is the subject of international co-operation, and which will require further development in future.

The required effectiveness of the controls and markers likely varies with the kind of intrusion anticipated. Although used fuel in a repository is retrievable, retrieval is not easy and requires specialised equipment. Location underground makes this retrieval more difficult. The used fuel is also protected from intrusions due to normal construction activities. Deliberate intrusion for archaeological, mining or military purposes would be a substantive undertaking, requiring considerable technology and industrial effort given the depth, rock and materials and purpose of the intrusion. Those making these efforts would likely either know or quickly recognize the nature of the facility, making the control or marker effectiveness a minor point. A society which developed large urban areas at the surface, with substantial drawdown of possibly contaminated water, would also seem likely to have sufficient technology to monitor the quality of the groundwater and identify and respond to any radioactive contamination, again regardless of whether site knowledge was retained. Durable controls or markers might therefore be of most use to prevent accidental penetration, when the risk would be inherently confined to a smaller group, and the probability of intrusion is also low

2.17 Project Management - Land and Resource Use

PARTICIPANT COMMENTS

Health Canada

Section 4.2.8 ... Section 4.2.10 ... neither of these Sections in the main EIS document specifically examines multiple resource and land uses in the context or mitigation measures ...the proponent does not discuss how concept implementation could relate to any regional or municipal land use plans or to resource management plans, such as the Ontario Ministry of Natural Resources Timber Management Plan. [Comment 940, Source Document gov006, Page 11]

There is a need for ... Preservation of the natural environment, particularly food, water, living off the land, hunting, fishing and trapping, because of consumption of country foods, and because national and international tourism is becoming an increasingly important business for aboriginals. [Comment 1009, Source Document ph2gov011, Page 16]

OPG RESPONSE

This comment is noted. The context for a deep geologic repository with respect to regional and municipal land use plans and provincial plans is an aspect which should be considered as part of siting feasibility studies.

2.18 Project Management - Occupational Health and Safety

PARTICIPANT COMMENTS

Concerned Citizens of Renfrew County

The issue of worker safety in a high-level waste facility is inadequately dealt with. There is virtually no discussion of worker protection, whether under normal operating conditions or in the case of serious accidents. [Comment 1963, Source Document pub031, Page 1]

Federation of Ontario Cottagers' Associations (FOCA) (Hunnius)

We are, however, deeply disturbed by the almost total absence of any discussion, in the EIS and the Primary References, on how work will be organized and supervised in the preclosure phase of used-fuel disposal.... We maintain that the way work is organized and supervised is a major factor in determining "human factors" such as stress and stressors, overload and underload, decision latitude of employees and supervisors, overtime, etc. All of these factors have a potential impact on the health of employees and the safety of the entire operation.... There is no evidence in the EIS indicating an awareness of the substantial scientific literature dealing with the Taylorist and post-Taylorist models of work organization and supervision and their respective impacts on health and safety.... our concerns lie with the absence of any description in the EIS dealing with the details of the social subsystem, in all stages of the preclosure phase [e.g., vertical and horizontal division of work, the organization of work and its coordination, conflict resolution processes, the role and function of the union, etc.] [Comment 2091, Source Document pub004, Page 01]

National Action Committee on the Status of Women

Very few details about health and safety measures and their enforcement are provided in the EIS. Instead, we are provided with a general discussion of regulations governing health and safety, and vague assurances that these regulations will be met. [Comment 1295, Source Document pub026, Page 33, Section 7.3.3]

National Council of Women of Canada

In the actual construction of the vaults, and especially during the storage phase of the work, what are the measures to be taken to prevent accidents. [Comment 2155, Source Document phpub035, Page 04]

OPG RESPONSE

The issue of worker safety at a deep geologic repository facility for used fuel is discussed in the EIS support document "The Disposal of Canada's Nuclear Fuel Waste: Preclosure Assessment of a Conceptual System" and covers normal and abnormal (accident) conditions, and conventional and radiological events.

OPG recognises that more extensive assessment and discussion on worker safety would be required for further design, approval and licensing of a real facility. OPG, AECL and other nuclear utilities in Canada and elsewhere, have gained considerable experience in operating nuclear facilities in a safe manner. The deep geologic repository would be licensed by the Canadian Nuclear Safety Commission, which would require safe operation for all workers.

2.19 Project Management - Emergency Response

PARTICIPANT COMMENTS

Health Canada

What provision is to be made for providing the appropriate emergency response equipment to the disposal site and to sites affected along the transportation routes? Will the emergency response capability be the same after the disposal facility is closed? If not, what emergency response provisions will be made? [Comment 999, Source Document ph2gov011, Page 12]

OPG RESPONSE

Emergency response capability would be part of the organisation at a deep geologic repository site, as at current nuclear sites. Under the Transportation of Dangerous Goods Regulations, an approved Emergency Response Assistance Plan is required for all transportation of dangerous goods. The plan would typically include notification, consideration of potential accidents, and preparation for response. First response would be provided by emergency services, who are trained and informed on the nature of radioactive materials transport. Specialist first response, including equipment, would be provided by nuclear sites, i.e. the DGR site, research sites, and nuclear station sites.

OPG believes that emergency response will not be required after closure of the facility.

2.20 Project Management - Maintaining Flexibility

PARTICIPANT COMMENTS

Canadian Geoscience Council

the committee recommends that: options regarding long-term storage and retrieval be reexamined continuously throughout the planning, construction, and monitoring phases. [Comment 1021, Source Document tec002, Page ii, Section ES]

Health Canada

Several of the points in the guidelines do not appear to have been included, including the flexibility to respond to changes in regulatory criteria and independent review procedures. [Comment 943, Source Document gov006, Page 12]

the AECL proposal should be open to the possibility of altering the disposal plan, part way through, should a safe, viable, more environmentally sound (including human health) disposal technology come into being either before or after the disposal concept is decommissioned. [Comment 996, Source Document ph2gov011, Page 10]

Joint Committee of the Canadian Academy of Engineering and the Royal Society of Canada

the Joint Committee endorses the concept on technical grounds but urges care once the concept proceeds to implementation. Ironically, the technical expertise and feasibility of the project threaten to make it inflexible, that is, its very superiority may encourage an attitude resistant to adaptation to changing circumstances and knowledge. And if there is one certainty in a project for which much is uncertain, it is that conditions will change during the lifetime of a project of two to three generations. [Comment 1176, Source Document ph3pub034, Page 2]

OPG RESPONSE

In 2002, OPG and the other nuclear energy corporations in Canada formed the Nuclear Waste Management Organisation (NWMO). The NWMO was established in accordance with the federal Nuclear Fuel Waste Act to investigate approaches for long-term management of Canada's used nuclear fuel. These approaches include, but are not limited to, on-site storage at reactor sites, centralised storage either above or below ground, and disposal on the Canadian Shield. The storage and deep repository concepts have been developed to be flexible to accommodate site conditions and potential changes in regulatory criteria (which are currently (2003) under review by the CNSC).

With respect to the deep geologic repository concept, the depth of the facility and layout of the vault are flexible to accommodate geological features and environmental conditions at the site. In addition, alternative emplacement methods for used fuel containers (in-room, in-floor, and, potentially, horizontal boreholes) are being examined as viable options in Canada pending site information and further engineering studies and analyses (Russell and Simmons 2003).

References:

Russell, S.B. and G.R. Simmons. 2003. Engineered barrier systems for a deep geologic repository in Canada. Proc. 10th International High-Level Radioactive Waste Management Conference, Las Vegas, USA.

2.21 Project Management - Multiple Sites

PARTICIPANT COMMENTS

Canadian Coalition for Ecology, Ethics and Religion

The implication is that a single consolidated facility is under consideration with the proposed concept, but this is not specifically stated and there is no discussion of the implication of a number of separate or dispersed disposal facilities. This needs to be addressed and the discussion will need to involve the future of nuclear power. [Comment 1844, Source Document phpub043, Page 38, Section 15]

Energy Probe (Brubaker)

Although required by the Panel to discuss "the implication of a number of separate or dispersed disposal facilities" (Guidelines, 12), nowhere does AECL examine whether multiple long-term disposal sites might be more easily sited than one repository. [Comment 2045, Source Document pub014b, Page 08]

Joint Committee of the Canadian Academy of Engineering and the Royal Society of Canada

the EIS ... should not remain silent on ... the broader implications of continued use of nuclear energy in Canada, when additional facilities will almost certainly be needed. By the time the first facility reaches post-closure, attitudes towards reuse of the fuel waste may have modified and energy needs of the day and the status of alternative sources may have resulted in many changes as a new generation of power stations comes into play. [Comment 1196, Source Document phpub031, Page 7]

Science for Peace (Energy Working Group)

the number of nuclear waste disposal sites should be kept to a minimum, preferably one.... we recommend one single site for Canada. [Comment 1716, Source Document ph2pub034, Page 5]

Transport Canada

The study should not be so short-sighted as to give the impression that one disposal site is all that is required to fulfill all present and future needs for HLRW disposal.... Estimates of the number of disposal sites required for the respective scenarios presented in the EIS [should] be evaluated and available for presentation [Comment 498, Source Document gov001, Page 3]

OPG RESPONSE

If the deep geologic repository approach is selected by the federal government following the Nuclear Waste Management Organisations study of alternatives, OPG expects that there will be a single facility in Canada for used CANDU fuel and other high-level radioactive wastes.

3 LICENSING

3.01 Licensing - Relevant Legislation

PARTICIPANT COMMENTS

Health Canada

the Workplace Hazardous Materials Information System (WHMIS) ... is not mentioned in the main EIS document, and neither is the federal Hazardous Products Act, and its regulations which contain the authority for the WHMIS. The provisions of the Act and its regulations should be included [Comment 933, Source Document gov006, Page 08]

National Council of Women of Canada

Burial of Nuclear Waste on the lands of indigenous peoples is dumping of hazardous waste. Canada has agreed to cease this practise under Paras 246, 247, 248, 250, 251 and 253 of the PFA... under the PFA paras mentioned above NCWC asks that AECL research other methods of disposal. [Comment 1498, Source Document ph3pub185, Page 5]

OPG RESPONSE

The need for inclusion of the Hazardous Products Act and its regulations among the applicable regulations is noted and agreed. At the outset of any disposal siting program, work would include a review of legal aspects, relevant legislation, agreements and commitments relating to development of a deep geologic repository..

3.02 Licensing - Provincial Approvals

PARTICIPANT COMMENTS

Scientific Review Group

no mention has been made of licensing approvals that must also be gained from the appropriate Provincial government to whom surface and mineral rights are invested. [Comment 70, Source Document tec004, Page 133, Section C-1.1]

OPG RESPONSE

This comment is noted and will be taken into account.

3.03 Licensing - Criteria

3.03.01 Licensing - Criteria - Contaminant Concentrations PARTICIPANT COMMENTS

Scientific Review Group

The effect of technetium ... could be large in comparison with the extremely small background concentrations ... The concentration is " ... less than 10-11 mg L-1 in lake water" (EIS 1994: p.244); this effect is dismissed without rational justification, on the basis of the assertion that since the concentration is very small, the environmental effect is expected to be very small. [Comment 474, Source Document tec004, Page 095, Section 7.7]

OPG RESPONSE

The status of chemical toxicity data for used fuel nuclides is reviewed in the Goodwin and Mehta (1994) screening study. For Tc, they report two references that provide qualitative information, and use (for screening purposes) a default drinking water limit of 10-9 mol/L or 10-4 mg/L. For comparison, the Health Canada guidelines for the maximum acceptable concentration of Tc-99 in drinking water from a radiological viewpoint corresponds to 3x10-4 mg/L (Health Canada 2002).

OPG plans to look further at chemical toxicity as part of the Third Case Study project and related reports (see Gierszewski et al, in preparation). Criteria for future safety assessments will be developed considering toxicity data, as well as comparison with naturally-occurring levels. In some cases, such as technetium, which is a rare element, arguments based on chemical analogues may be needed.

References:

Gierszewski, P.G. et al. Third Case Study postclosure safety assessment, OPG Report 06819-REP-01200-10109-R00 (in preparation).

Goodwin, B. and K. Mehta. 1994. Identification of contaminants of concern for the postclosure assessment of the concept for the disposal of Canada's nuclear fuel waste. Atomic Energy of Canada Limited report AECL-10901.

3.03.02 Licensing - Criteria - Environmental Increments PARTICIPANT COMMENTS

Scientific Review Group

What the postclosure document considers a tolerable impact of a contaminant (the incremental effect of one standard deviation of its local concentration in nature) would not necessarily be widely accepted. [Comment 139, Source Document tec004, Page 163, Section E-2.1.1]

The Environmental Increment approach developed by AECL for the evaluation of radiological and chemical impacts in the environment is logical; however, it does not incorporate the recent advances in the assessment of ecological risk. Furthermore, the use of environmental increments would have been more convincing had specific ecological receptors been identified rather than the generic bird, plant, etc [Comment 163, Source Document tec004, Page 176, Section E-2.1.5]

The Environmental Increment approach resembles approaches currently in use in ecological risk assessment; however, it does not formally identify the Environmental Increments as assessment endpoints or measurement endpoints. ... the Environmental Increment approach used by AECL does not make use of toxicological data (such as NOEL's or effect- concentrations (EC50's)); rather, it depends solely upon a comparison with background concentrations. Therefore, while the AECL approach is logical and based upon a good understanding of the range of background concentrations, it is not as convincing as it could have been had toxicological information also been incorporated into the risk analysis. [Comment 187, Source Document tec004, Page 188, Section E-3.2]

OPG RESPONSE

By definition, the standard deviation is within the normal range of background. Further work is required to establish the health of existing ecosystems under this variation. OPG agrees, as noted in its response to 3.03.01, that criteria based on environmental increments should be supplemented by an understanding of the toxicology and no-effects levels.

It is expected that the repository program will be the subject of an ecological risk assessment at a sitespecific stage, which will include identification of specific ecological receptors, assessment endpoints and measurement endpoints, and will use available appropriate methodology at that time.

3.03.03 Licensing - Criteria - Decommissioning and Closure

PARTICIPANT COMMENTS

Graham, J.

Final closure of the facility should only be approved after successful performance has been achieved. [Comment 1416, Source Document ph3pub060, Page 3]

Health Canada

The EIS does not supply a clear statement of criteria upon which the decision to close and decommission the proposed vault will be based. A discussion of the type of evidence and the nature of monitoring should be included. [Comment 932, Source Document gov006, Page 08]

The EIS does not discuss in detail 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. [Comment 946, Source Document gov006, Page 13]

It is not indicated as to what constitutes sufficient evidence to lead to the closure of a disposal facility without the need for extended monitoring. What are the criteria? [Comment 1000, Source Document ph2gov011, Page 12]

OPG RESPONSE

Criteria for closure will be decided by the community, regulator and other institutions involved at the time, and with the knowledge that exists at that time. Clearly the criteria should include a comparison of the repository behaviour with expectations, via observation, monitoring, measurement etc. Criteria will be developed in the context of making provision in designs to provide this information.

It is expected that monitoring may be continued for as long as the host community requires, in consultation with the regulator.

3.03.04 Licensing - Criteria - Comparability

PARTICIPANT COMMENTS

Campaign for Nuclear Phaseout

The current AECL and regulatory criteria for radioactive emissions from nuclear facilities embody an unjustifiable and unsustainable "double standard". This double standard allows people and the environment to be subjected to much larger risks from radioactive emissions than would be considered tolerable from other kinds of toxic and carcinogenic substances. [Comment 1818, Source Document pub027, Page 34, Section III.H]

Energy Probe (Rubin)

There is an important "double standard" at work: the levels of cancer risks considered "acceptable" for radioactive pollutants are generally much greater than those considered "acceptable" for non-radioactive, "chemical" pollutants. [Comment 2068, Source Document phpub041, Page 06]

OPG RESPONSE

Criteria for radiation protection are based on those developed by ICRP taking account of the risks which appear to be generally considered acceptable. However, there are a number of conservatisms in risk assessment methodology for radionuclides which lead to very low risks, in practice, to people exposed via environmental pathways. For example, while chemicals are considered singly in setting target levels, the doses from all radionuclides are added together for comparison with criteria. This approach is now seen as desirable for chemical contaminants also (see for example the July 2001 Ontario Ministry of the Environment Review of Best Practices). There are also conservatisms in safety assessments used to demonstrate compliance with regulatory criteria. A Health Canada/AECB/Ontario MOEE working group concluded in 1998 that risk management strategies for regulated practices for both radiation and genotoxic chemicals provide a high degree of health protection, and it was not possible to determine whether environmental exposures to ionizing radiation or genotoxic chemical carcinogens posed a greater risk.

Regulatory criteria are the responsibility of CNSC, and requirements for disposal are expected to be further developed in future with public consultation.

However, in addition to showing that designs meet applicable criteria, projections of potential health effects would be made as part of the EA for any future facility.

3.03.05 Licensing - Criteria - Protection of Humans

PARTICIPANT COMMENTS

Campaign for Nuclear Phaseout

In attempting to determine "acceptable" levels of risk, questions that need to be asked include: - How is the decision made that 'x' number of cancers per year, per million population, is an acceptable risk?

- How are criteria established for a concept which will potentially expose people to harm for millennia? [Comment 1819, Source Document pub027, Page 35, Section III.H]

Canadian Voice of Women for Peace

Standards of the regular risks under which the nuclear industry operates are not adequate for a project of this magnitude. [Comment 1913, Source Document pub003, Page 02]

Catholic Women's League of Canada - Ontario

independent scientists have questioned the Atomic Energy Control Board's weak standards employed with respect to acceptable amounts of radiation. [Comment 1930, Source Document ph3pub209, Page 2]

Concerned Citizens of Manitoba

Even a very small risk coefficient becomes unacceptably high when multiplied by two very large variables - huge lengths of time and massive potential damage to the environment. [Comment 1958, Source Document phpub153, Page 7]

The levels of acceptable radiation used in determining the levels of risk for the various activities involved with developing a disposal facility are based on current industry standards. While these levels are considered acceptable today, it is important to recognize that the levels considered acceptable are regularly being reduced, and that no safe level of radiation exposure exits.... Because of the extreme time-lines involved in the release of radioactivity from nuclear waste, these changes in what is considered acceptable should be taken into account and extrapolated into the future. [Comment 1948, Source Document pub034, Page 2]

Energy Probe (Rubin)

establish stringent regulatory standards for total population ... risks [Comment 2065, Source Document phpub041, Page 05]

Before a nuclear waste repository is authorized, we must have a very high level of confidence that it will not expose any future individual to health risks that today's relatively risk--averse individuals would object to.... We suggest that the "very high level of confidence" be set, at the very least, at the 99% confidence level (p=0.01, one-tailed), after incorporating all the uncertainty in the entire analytical process: the uncertainties in individual parameters, the models' calculated ("Monte Carlo") uncertainty, and the independently estimated uncertainty that the models are incomplete, simplistic, or otherwise wrong.... when dealing with dreaded diseases like cancer, leukemia, and serious hereditable defects, it is very easy to find members of the public indeed, a significant portion of the public - who will object to any imposed, non-zero risk. [Comment 2067, Source Document phpub041, Page 05]

The Panel must expressly reject AECB's regulatory approach to nuclear waste, specifically its suggestion that it would be "acceptable" for our generation's nuclear-waste repository to expose individual future Canadians to risks of fatal cancer and serious genetic effects of 10-6 per year or even higher, within the first 10,000 years after closure, and still higher risks in subsequent years. [Comment 2069, Source Document phpub041, Page 09]

If the Panel wishes to adopt a non-zero definition of "acceptable risk" for future human individuals, from the planned repository, we recommend the following ... Combining these recommendations, the maximum "acceptable" dose to the most exposed future individual, at our (one-tailed) 99% confidence limit would be calculated as follows: $1 \times 10-6$ lifetime cancer risk/ 0.15 total cancers per Sievert = 6.7 microsieverts (6.7 x 10-6 Sv) over a lifetime. Assuming (pessimistically) only 76 years per average lifetime yields a maximum acceptable annual dose of roughly 88 nanoSieverts (8.8 x 1 0-8 Sv) per year. [Comment 2070, Source Document phpub041, Page 10]

Rather than merely providing adequate protection for the average member of the public, the Panel should also seriously consider providing adequate protection for individuals who are more radiation-sensitive than average. [Comment 2071, Source Document phpub041, Page 11]

We have found several brief references to the notion of "acceptable risk", but no definition, as requested on p. 9 of the Guidelines. [Comment 2058, Source Document pub014r, Page 7]

Health Canada

the standards applied and the decisions made concerning dosage and safety should be based on prudence and concern for the special conditions of exposure and sensitivity of aboriginal people. [Comment 1015, Source Document ph2gov011, Page 18]

International Institute of Concern for Public Health (Bertell)

What is not clear, is the number of fatalities per year considered "acceptable" during the construction, transportation and operational phase. [Comment 2116, Source Document ph2tec002, Page 03]

if you asked how many would die of cancer per million persons exposed, without specifying a time limit, I believe that you would find the number quite unacceptable. [Comment 2119, Source Document ph2tec002, Page 03]

National Action Committee on the Status of Women

the EIS does not address the problems inherent in the radiation exposure standards for women workers and the public.... the effects on women of radiation exposures both above and below current standards are key to understanding the potential impacts of the proposed concept on women's health under both normal and accident conditions. [Comment 1280, Source Document pub026, Page 23, Section 7.2]

AECL relies primarily on stating that it will meet standards currently in place for radiation exposure without exploring the adequacy of these standards for women. [Comment 1284, Source Document pub026, Page 28, Section 7.2.6]

The EIS makes much of stating that exposure levels resulting from the proposed concept will be far below current and proposed standards for both public and worker exposure. The EIS makes no effort to examine the adequacy of these standards as required by the Guidelines [Comment 1285, Source Document pub026, Page 29, Section 7.2.7]

There is no discussion of the adequacy of standards for women workers, and in particular pregnant workers, in the EIS. [Comment 1294, Source Document pub026, Page 33, Section 7.3.2]

The ALARA Principle ... leaves open who decides what is reasonable, or what social and economic factors are being considered, and by what criteria they will be "taken into account", creating the same margin for uncertainty and bias that risk assessment does [CLC 1984]. Therefore the assertion that doses will be kept ALARA, social and economic factors taken into account does not guarantee any particular dose level, or any level of impact that we can then evaluate. [Comment 1310, Source Document pub026, Page 51, Section 7.7.5]

Northwatch

the EIS should discuss the acceptability of container failure, and set out the threshold for that acceptability ... the contaminant release should be discussed in both a temporal and spatial sense, and in terms of its medium and long-term impacts [Comment 1370, Source Document pub046, Page 14, Section d]

Northwatch (Jackson)

The only definition of acceptable risk that should be used as a guideline is the definition of acceptable risk that the most severely affected consider acceptable. [Comment 1528, Source Document ph2tec031, Page 04, Section 05]

Ontario Association for Environmental Ethics

the assertion of an equivalent relation between relative frequency and an individual's potential for disease and death has no basis whatsoever in science (reality).... In disease, such potential is a function of the relation between the nature and quantity of the agent and the nature of the individual... asserting through a relative frequency/probability statement that each individual in a population has the same potential is valid only if it is also shown that individuals are identical in the relevant respects. [Comment 1627, Source Document phpub088, Page 15]

if frequency data are generated from a 'risk' assessment based on the reference person/most sensitive individual, for example that, at a predicted dose, 1 individual out of 1,000,000,000 is predicted to die, it is incorrect to assert that all individuals of the population have a potential of 0.000001, even for those who are not sensitive (have a predicted potential of 0 at the predicted dose) but particularly for the individuals in the population who correspond to the 'reference person' or are more sensitive than it because the predicted potential for these individuals is 1. [Comment 1628, Source Document phpub088, Page 16]

disease is a function of a particular individual's constitution relative to the agent. It is a non-random event in the sense that equiprobability does not obtain between individuals and when individuals are exposed to an agent there is no non-selective process. Hence, relative frequency is an irrelevant measure of both potential and uncertainty. [Comment 1629, Source Document phpub088, Page 24]

If, in fact, what is being predicted in a 'risk' assessment is the expected frequency of adverse effects or future harm, there is no need even to bring the concept of risk into consideration. Of course, there will be uncertainty in any calculation or prediction of frequency but, when uncertainty concerns the accuracy of predictions, it does not create an obstacle to decision making. For example, if a prediction of 100 deaths is highly inaccurate and the true figure is only 1, we still face the moral problem of causing that one death, and those who care about that one person face the emotional trauma of such a loss. [Comment 1630, Source Document phpub088, Page 28]

The case of small populations (e.g. 100) exposed to very low doses is problematic where the prediction of relative frequency of disease is very low (e.g. 1/1,000,000). Simply comparing the two figures may not suffice in assessing the degree of risk (uncertainty). Rather, one may have to reach deep into toxicological/epidemiological decisions and concepts to establish the grounds for assessing risk, if in fact it turns out to be risk. [Comment 1634, Source Document phpub088, Page 28]

Robertson, J.A.L.

An essential point that receives inadequate recognition is the very understandable attitude that any risk, however small, is unacceptable unless there is perceived to be some corresponding benefit that is wanted. [Comment 1453, Source Document phpub004, Page 14]

United Church of Canada

The EIS [AECL, 1994] fails to address the scope of the potential for harm of the nuclear waste.... Even if the best assurance is one of extremely high probability of 'safety', the risk may not be worth it when the potential for harm that would result from the low-probability event would threaten the continuation of life. [Comment 1738, Source Document phpub124, Page 3-16, Section 3]

OPG RESPONSE

Radiation protection standards are set by CNSC following international consensus. Among the factors used in development is comparison with other sources of risk. For disposal, special criteria have been developed to recognise the uncertainties involved in projecting exposures far into the future.

Knowledge relevant to the issue of radiosensitive individuals will likely advance over the next decades and may affect radiation protection criteria. However, review by ICRP (ICRP 1999) has not led to a need for any change in dose limits.

CNSC is carrying out a review of its regulatory guidance documents, and will seek public input. Issues could be the applicability of current international standards to both sexes and all age groups. At present, it is recognised that the precision in the estimates of risk per unit dose is not such as to warrant the introduction of separate standards. This is compensated for by the conservatisms incorporated in assessments.

OPG applies this standard to the maximum estimated annual dose over time. The criteria applied will be those pertaining at the time of facility licensing. It is intended to take account of special conditions, for example aboriginal diet and lifestyle, in safety assessment.

The methodology used for safety assessment involves the calculation of doses to the most exposed group of individuals. The doses calculated would be expected to apply to only a small group, and doses to the rest of the population would be much smaller because of the conservative assumptions made in the calculation. (See also discussion in response to comments in Category 4.07.01.)

A number of 'what if' scenarios will be explored (see also points related to multiple barriers, category 2.05.01, 2.05.02 and 2.05.03). These will include low probability scenarios. However, it may be noted that no accident to the repository could cause a threat to the continuation of life.

Temporal variation in doses is already done as part of identifying the maximum dose. Work on examining the realistic evolution of a repository has been carried out by OPG (McMurry et al. 2003) and this aspect is receiving more attention in future presentation of risks. (It should be noted that the fact the exposure may continue, or potentially continue, for a very long time, does not affect the magnitude of the individual risk.) The host community, acting as a surrogate for future communities, will have a role in deciding on the acceptability of risk during their negotiations during implementation. The regulator also represents the interests of future generations, as well as current generations.

Further review of ethical issues is being carried out as part of the review of options required by the Nuclear Fuel Waste Act. It is noted that risks and benefits will be taken into account in the process of selecting an option for

management of used fuel, and would have to be further examined during as part of EA and hosting agreements during a site-specific stage.

Reference:

McMurry, J., D.A. Dixon, J.D. Garroni, B.M. Ikeda, S. Stroes-Gascoyne, P. Baumgartner and T.W. Melnyk. 2003. Evolution of a Canadian Deep Geologic Repository: Base Scenario. Ontario Power Generation Report 06819-REP-01200-10092-R00.

ICRP (International Commission on Radiological Protection). 1999. Genetic Susceptibility to Cancer. ICRP Publication 79, Elsevier Publishing.

3.03.06 Licensing - Criteria - Protection of Non-Human Biota

PARTICIPANT COMMENTS

Canadian Coalition for Ecology, Ethics and Religion

For the in-room emplacement case, the dose rate limit for non-human biota is set at 1 mGy/a, which relates to 20 to 200 times higher than that permitted for humans (depending on the form of the ionizing radiation) and model evaluation is limited to three animals and a plant within a simplistic scheme. As noted for the EIS case, this approach is entirely inadequate to address the complex issues of environmental protection with the level of certainty necessary for the application to which it has been used. [Comment 1872, Source Document ph3pub160, Page 7]

Catholic Women's League of Canada - Ontario

In a study conducted by AECL's Pinawa researchers, ... it was concluded that the germination rate had a deleterious effect at 1.1 mGy (milligrays) per hour. The conclusion of the experiment leads to many questions regarding the forest, the berries, the fauna, the fruits, vegetables and grains; indeed all seed-bearing plants. [Comment 1932, Source Document ph3pub209, Page 3]

Energy Probe (Rubin)

establish stringent regulatory standards for ... environmental risks [Comment 2133, Source Document phpub041, Page 05]

Environment Canada

the discussion of acceptability criteria for ecological effects ... is very general. The notion that the significance of effects will be judged in terms of magnitude, extent, duration, frequency, reversibility and ecological context should be developed further at the concept stage to focus future discussion, rather than waiting for the siting phase. A framework which identifies and provides a rationale for ecological acceptability criteria should be provided. Statements that existing standards and guidelines would be adhered to are inadequate, since many potential effects do not have well-established acceptability criteria. [Comment 889, Source Document gov003, Page 33, Section 2.15]

There is no explicit mention of risk and what would constitute acceptable risk in the discussion of the significance of ecological effects. The definition of what constitutes acceptable risk should be clearly stated. [Comment 890, Source Document gov003, Page 33, Section 2.15]

Robertson, J.A.L.

The EIS (AECL-10720, page 10, section 1.2.4) argues that limiting the risks to individuals and to populations incidentally protects this environment.... this argument has been challenged in the literature ... the EIS does not mention that consideration has to be given to possible exceptions to its generalization, such as:

- If an endangered species were to be exposed to substantial radiation, harm to individuals could harm the species.

- If a breeding ground for some species were to be contaminated by radioactive material, there is potential for harm to a large population. [Comment 1457, Source Document phpub004, Page 27]

United Church of Canada

There is inadequate peer-reviewed, scientific data for the conclusions that the additive dose of ionizing radiation presently permitted in radiation protection standards for humans will assure safe conditions for non-human life.... The studies on biota have not followed long-term effects and extrapolations have been from mortality and natality based harm indicators. Most biota ionizing radiation impact studies lack ecological realism and fail to produce data suitable for extrapolation to actual situations.... There has been very little attention to long term effects of chronic low level radiation, patterns of repair, etc.; the longest studies are a few years, whereas it may take decades to express damage at the population or community level.... Most of the biota studies have insufficient range of dose rates to produce data suitable for extrapolations of low level environmental contamination. [Comment 1747, Source Document phpub124, Page 3-21, Section 3]

United Church of Canada (Cambrian Presbytery)

Environmentally the Concept must meet safety and protection standards for biota. However, there are no such standards presently in place and protection standards that have been established for humans do not adequately address this need. The standards and regulations required should be established by a process that values public input. A review group of ecologists, biologists and ethicists should be assembled to evaluate the assumptions, method, models and conclusions concerning the potential impact on biota. [Comment 1759, Source Document ph3pub041, Page 6]

OPG RESPONSE

At the time AECL's EIS was written, methodology for ecological risk assessment for nuclear facilities was not well developed. AECL were in fact pioneering the methodology, particularly in view of the nonsite-specific nature of the assessment. This made it difficult to follow an approach which included identification of spatial and temporal boundaries, identification of valued ecosystem components, etc. The approach taken was, from review of the literature, to choose a dose criterion at which no effects would be expected in any species. This criterion was then applied to doses calculated using a conservative representation of 'reference biota'.

Prior to the 1990s, it was assumed that if humans are protected, then other species are also. This assumption was based on the fact that humans are among the most radiosensitive mammalian species. During the 1990s, a number of initiatives displaced this assumption. Reviews by IAEA (1992) and UNSCEAR (1996) summarised the current state of knowledge of the impact of radiation on plant and animal populations. These initiatives, however, continued to be based on the view that for most organisms it is the population that is important. While there may be exceptions, e.g. in the case of rare species and those which reproduce slowly, in general it is therefore such effects as reproductive success and population viability which are of interest. In the light of these reviews, AECL' s criterion of 1 mGy/a is very conservative. The IAEA/UNSCEAR reviews suggest a general criterion of 400 mGy/a for terrestrial animals and 4 000 mGy/a for plants and fish. Further examinations of protection of the environment from the effects of radiation are being carried out by ICRP, UNSCEAR and IAEA, which are working towards the development of an international framework, data, and criteria.

In Canada, two initiatives have taken place which will assist both in developing methodology, particularly screening methodology (i.e. where detailed site-specific information is not available) and in formalising the approach and demonstration of protection of the environment. The first is specific inclusion of protection of the environment in the CNSC's regulations under the Nuclear Safety and Control Act, accompanied by issue of a CNSC Policy on protection of the environment. Secondly, releases of radionuclides from nuclear facilities were included on Environment Canada's Second Priority Substances List as a 'substance' to be assessed under the Canadian Environmental Protection Act. A major effort in literature review and derivation of screening Expected No Effects Levels has been carried out by CNSC staff in support of Environment Canada. OPG has been involved in review of the PSL2 drafts and is following developments. Work has also been carried out by AECL, for example, an ecological risk assessment for the prospective IRUS facility at Chalk River. It is

noteworthy that recent and current work uses the dose conversion factors developed for the reference biota for the disposal concept EIS.

At the site identification stage of a future disposal program, it is expected that a screening assessment will be carried out for each candidate site. As part of this, it is envisaged that the following basic steps will be part of the assessment:

- 1. Identification of environmental discharge area from proposed disposal facility.
- 2. Ecological baseline study and survey of this area.
- 3. Identification of valued ecosystem components.
- 4. Identification of assessment and corresponding measurement endpoint.
- 5. Entry characterisation of radionuclides, including radionuclide screening.
- 6. Exposure characterisation establish expected exposure values for endpoints.
- 7. Radiation effects characterisation establish expected no-effects values for endpoints.
- 8. Risk characterisation.
- 9. Risk evaluation and management.

For the preferred site, an ecological risk assessment will be part of the Environmental Assessment required for the construction license. At that time, the latest international and CNSC guidance, methodology and criteria will be followed.

There is no unique methodology required for disposal. OPG's current program includes review of developments in this area. Some work is being carried out on methodology (see response to 4.06.03.01). Additional expertise will be developed/acquired as needed, and development of a framework for assessment will be the subject of a future work program.

3.04 Licensing - Demonstrating Compliance

PARTICIPANT COMMENTS

OECD/NEA Review Group

There is room for interpretation in those areas of the Canadian regulations associated with timeframes, particularly:

- The 10,000 year 'cut-off' beyond which dose estimates are not required.

- The meaning of 'sudden and dramatic' releases and 'acute' doses to individuals for times beyond 10,000 years.

- What comprises or is expected of a 'reasoned argument' in this period.

- The definition of critical group in different circumstances.

The Group recommends that, as part of further concept development, dialogue with AECB take place to resolve these issues. These talks should also address the issue of suitable performance measures to support quantitatively the required "reasoned arguments" in the time period after 10,000 years. [Comment 1220, Source Document tec001, Page 12, Section 4.1]

The Group believes that the treatment of human intrusion requires further discussion between the regulatory authority and the proponent as it may not be amenable to consideration within the normal safety assessment framework. In this respect, the situation in Canada is little different to that in most other countries. [Comment 1236, Source Document tec001, Page 15, Section 4.3]

Scientific Review Group

There is little indication how the legislation and regulations presented in R-Preclosure, were applied specifically to the information, data and quality assurance procedures that are required for preclosure assessment, and that must be followed through the various phases of implementation [Comment 107, Source Document tec004, Page 147, Section D-2.1.10]

OPG RESPONSE

The lack of clarity in some aspects of the regulatory guidance available at the time the EIS was prepared is recognised, and will be brought forward when a consultative document on revised guidance is made available by CNSC. In current safety assessments, OPG looks at the time of maximum dose, rather than the dose up to 10 000 years, while recognising increased uncertainty with time. Development of appropriate additional safety indicators will be explored, based on international work in this area (e.g. Gierszewski et al., in preparation).

We agree with the comment regarding human intrusion; this has received attention recently from ICRP in their Publication 81. Aspects requiring consideration are the expected lower likelihood of human intrusion (as opposed to the 'normal' case - which is itself an artificially-constructed conservative scenario but which is assumed to have a probability of 1), the fact that intrusion cannot be completely designed out, and the small size of the most highly-exposed group, for example a drilling crew.

In addition to CNSC regulations, there are many regulations to be complied with in the preclosure phase, and review and compliance with these would be an important part of the project at the site-identification and subsequent site-specific stages.

Reference:

Gierszewski, P.G. et al. Third Case Study postclosure safety assessment. OPG Report 06819-REP-01200-10109-R00 (in preparation).

3.05 Licensing - Definition of Risk

PARTICIPANT COMMENTS

Campaign for Nuclear Phaseout

risk analysis ... should be based on more than mortality figures. An alternative approach could focus on immune system response. [Comment 1820, Source Document pub027, Page 35, Section III.H]

Energy Probe (Rubin)

There is no attempt made to estimate the non-fatal cancers (or non-fatal genetic effects) that the planned repository will cause.... Any suggestion that an AECL-induced non-fatal cancer is not a health effect is a deficiency in common English usage and common decency, as well as in responding to the Guidelines. [Comment 2053, Source Document pub014r, Page 5]

Health Canada

the concept focuses on fatal cancers and serious genetic defects only. There is no mention of non-fatal conditions. [Comment 919, Source Document gov006, Page 03]

Risk should be defined to include non-radiological as well as radiological effects. [Comment 960, Source Document gov006, Page 17]

One component missing from the EIS is a description of what constitutes a definition of risk for non-radiological contaminants. [Comment 971, Source Document gov006, Page 18]

International Institute of Concern for Public Health (Bertell)

Stochastic effects counted as detriments by ICRP include only radiation induced fatal cancers and what it deems to be serious hereditary effects. It excludes from its estimates of "detriment" non-fatal cancers induced by the radiation, cancers due to other causes but promoted by radiation, benign tumours, autoimmune diseases (like juvenile diabetes, Hashimoto thyroiditis, or rheumatoid arthritis), non-serious hereditary diseases, and congential diseases or malformations which are not hereditary. It also excludes damage to the embryo or fetus which results in spontaneous abortion or stillbirth. Any organic or functional damage which is temporary or reversible ... was already excluded from concern under the selection of important deterministic detriment made by ICRP. [Comment 2121, Source Document ph2tec002, Page 09]

in regulating toxic exposures, most scientists recognize subclinical and moderate effects of exposure as detriments. For radiation exposure, only the most severe effects, like cancer death, are even recognized and acknowledged as "detriments". [Comment 2122, Source Document ph3pub105, Page 1]

Natural Resources Canada

The EIS treats the requirement of the guidelines not to restrict the discussion of health effects to mortality very lightly. For example, section 2. 1. 7 mentions the possibility of non-genetic and non-fatal cancers but does not discuss their implications on the health of individuals or communities section 7.9.1 of R-Preclosure concentrates entirely on fatal cancers. [Comment 713, Source Document gov005, Page 33, Section 8.3]

Scientific Review Group

Potential consequences not discussed include the risk of developing non-fatal cancers or genetic damage [Comment 472, Source Document tec004, Page 095, Section 7.7]

United Church of Canada

The public needs information on and protection from genetic damage including diseases of complex genetic origin, which comprise the largest category of genetic damage and which have not been included in estimates of total genetic damage. Adequate protection must be assured for the gene pools of all species, human and non-human. [Comment 1732, Source Document phpub124, Page 3-05, Section 3]

The public needs to be aware of the quality of the scientific bases upon which the standards are set, the degree of influence that feasibility and economic issues of the industry have on the setting of the standards and the risks, not just in terms of fatal cancers and serious genetic diseases as presently defined, but risks in terms of a full range of health effects. [Comment 1740, Source Document phpub124, Page 3-17, Section 3]

OPG RESPONSE

OPG's current safety assessment approach takes account of the risk of fatal cancers, non-fatal cancers and serious genetic effects as a consequence of dose, using the values of risk coefficient recommended by ICRP 1991. In assessing the possibility for other radiological risks, the very small doses projected, and the small size of the group exposed to the highest doses, should be recognised. These doses are very far below the level at which deterministic effects are seen, and are very small compared with background radiation levels (see also response to category 3.03.05). Data on the effects of radiation are regularly reviewed by bodies such as UNSCEAR, the BEIR committee in the US, and ICRP, and incorporated in the internationally accepted dose-risk estimates.

As part of the estimation of impacts for a future EA, non-radiological impacts would also be estimated. We anticipate that these risks will be assessed according to then-current Canadian best-practice for licensing of related types of facilities.

3.06 Licensing - Definition of Health

PARTICIPANT COMMENTS

Concerned Citizens of Renfrew County

The definition of health in the EIS is far too narrow, even insofar as individual health is concerned. Moreover, the community and social aspects of the concept of health are simply not dealt with. [Comment 1967, Source Document pub031, Page 3]

Health Canada

Neither definition of health mentions the community and social dimensions of health ...Section 6.11.2 of the main EIS document (p.254) outlines the characteristics of a community that determine its capacity for evaluating and managing environmental effects: social and cultural vitality, economic viability and political efficacy. These should be elaborated upon as some of the community and social dimensions of health. [Comment 929, Source Document gov006, Page 07]

The WHO definition of health should be clearly stated and used throughout the documents. The full dimensions of human health -- physical and psychological, community and social -- should be more thoroughly discussed in the documents. This includes the impact on local economies, employment situation, and multiple land use. [Comment 964, Source Document gov006, Page 17]

It is a serious limitation of the EIS that AECL continues to define human health in the very narrow sense of "a fatal cancer or serious genetic effect" rather than in the broader sense of the World Health Organization definition of health as "a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity". At the very least, the risk of non-fatal cancer should be included and there should be a discussion of other effects reported in the literature for exposure to low level radiation. To this should be added the effects of stress and anxiety on a host community and surrounding populations. [Comment 984, Source Document ph2gov011, Page 03]

OPG RESPONSE

These comments are noted. It is anticipated there would be future consultation with Health Canada and with other stakeholders during development of submissions for Environmental Assessment and licensing.
3.07 Licensing - Definition of Safety

PARTICIPANT COMMENTS

Canadian Coalition for Ecology, Ethics and Religion

Radiation protection standards do not represent levels of absolute safety but compromises, extrapolations, projections of risks deemed acceptable by an official body. To use these levels as though they offer a guarantee of safety for humans is to ignore the bases of these standards and the built-in risk acceptance. To use these levels as though they offer some guarantee of safety for non-human life is open to formal challenge. [Comment 1838, Source Document phpub043, Page 29, Section 11]

Concerned Citizens of Renfrew County

Don't accept a redefinition of "safety" as "meeting current standards" [Comment 1968, Source Document phpub171, Page 1]

Concerned Citizens of Renfrew County and Area

The EIS used an unfortunate definition of "safe" which implies that current standards are adequate to protect health, which is not the case. [Comment 1977, Source Document ph3pub216, Page 01]

Energy Probe (Rubin)

Guidelines, page 11, calls on AECL to discuss not only "a definition of safety in relation to the concept", but also "an outline of what would constitute adequate proof of safety." ... we can find no such outline. [Comment 2059, Source Document pub014r, Page 7]

International Institute of Concern for Public Health (Bertell)

The claim of conformity with regulations can not be substituted for real protection of human health [Comment 2115, Source Document ph2tec002, Page 01]

Robertson, J.A.L.

The most important omission from the EIS section on ethics is any discussion of the question "How safe is too safe?" [Comment 1455, Source Document phpub004, Page 24]

OPG RESPONSE

Radiation protection standards that would be used for licensing of a deep geologic repository are developed taking account of internationally-accepted dose-risk estimates and of consideration of other societal risks. Generally, because of conservative safety assessment methods and assumptions, estimates for licensing purposes which meet these standards include a wide margin of safety. For a future Environmental Assessment for a repository, the impact in terms of expected human and non-human (ecological) health effects will also be estimated.

The standard represents a very high level of safety when compared with other risks.

The safety case for a deep geologic repository is expected to include a number of complementary arguments which together constitute adequate proof of safety. The constitution of the safety case is to be developed and will be subject to ongoing discussion with the regulator and other stakeholders.

3.08 Licensing - Circumventing an Environmental Assessment PARTICIPANT COMMENTS

FARTICIFANT COMMENTS

Concerned Citizens of Renfrew County

Amend laws that circumvent environmental assessment for siting of wastes at facilities with existing AECB licenses ... under the Canadian Environmental Assessment Act ... permanent disposal of ANY amount or type of radioactive waste would receive comprehensive study. However, existing licensed facilities such as AECL Chalk River are exempt from this provision. This exemption may create an incentive to locate radioactive waste disposal sites at existing licensed facilities to avoid costly environmental assessments. [Comment 1976, Source Document phpub171, Page 4]

OPG RESPONSE

A deep geologic repository, wherever sited, would be subject to the Canadian Environmental Assessment Act.

If located completely within the boundaries of an existing licensed nuclear facility, the initial stage of environmental assessment (EA) could be preparation of a screening report (screening EA). At this stage, CNSC, the responsible authority, can require any studies necessary to enable it to make a determination of a course of action. It can also give opportunity for public comment on the screening report, and these comments would be considered by CNSC in making a determination. CNSC's determination following consideration of the screening report may be to allow the project to proceed, in whole or in part, not to allow the project, or to refer the project to the Minister for panel or mediator review. Referral may be based on uncertainty, likely significant adverse environmental effects, or public concern.

If located outside the boundaries of an existing nuclear facility, a comprehensive study would be required. The differences with a comprehensive study (as opposed to a screening study) are as follows:

- the decision on whether to refer the proposed project to a panel is made early in the process;

- the scope of the study includes the purpose of the project, alternative means of carrying it out, any follow-up program, and effect on renewable resources;

- a public comment period following preparation of the comprehensive study report is mandatory, and

- the decision on a course of action, either to allow the proposed project to proceed, in whole or in part,

or not to allow it to proceed, is taken by the Minister.

The decision whether or not to carry out a formal panel review therefore rests with CNSC and the Minister, not with the proponent.

Furthermore, there are many technical, social and financial factors to be taken into account in identifying a site and in obtaining approval to construct a facility. The time and cost of the EA process is a very significant factor. But social acceptance is also an important part of the siting and EA process.

3.09 Licensing - Radiation Emission Standards

PARTICIPANT COMMENTS

Concerned Citizens of Renfrew County and Area

DELs do not adequately take into account

- total population exposures;
- build up of radioisotopes with half lives of months to millennia in humans and food chains;
- cumulative effects of multiple emissions sources in a local area;

- variation in human susceptibility to radiation-induced diseases. [Comment 1979, Source Document ph3pub216, Page 03]

OPG RESPONSE

DELs (Derived Emission Limits) are used in control of emissions from operating nuclear facilities. (OPG's DELs have been replaced with Derived Release Limits calculated according to new methodologies.) They provide a means to relate emissions to the radiation dose received by the relevant critical group.

Generally, emissions are controlled to a small fraction of the DEL. This recognises both uncertainty in the estimates, and the historically-low emissions from nuclear stations, implying that low levels are ALARA. Confirmation that doses are indeed low and well below regulatory limits for members of the public is provided by environmental monitoring and sample measurement. The methodology of this confirmation is such that it includes build-up of radionuclides, and multiple sources.

It is expected that emissions during the operational phase of a repository would be similarly monitored and controlled. However, for the control of postclosure exposures from a deep geologic repository, DELs would not be the method used. Instead, CNSC set criteria, and safety assessment would be used to show that these criteria were met.

The question of population exposures has yet to be resolved, since there are many uncertainties in projecting population distribution far into the future. This is not currently a regulatory criterion, because it is not clear if it can be usefully estimated.

Build-up of radionuclides is included in the models used for assessment.

Variation in human susceptibility is discussed in the response to category 3.03.05.

4 SYSTEM PERFORMANCE

4.01.01 System Performance - Activities - Outcrop Clearing

PARTICIPANT COMMENTS

Scientific Review Group

detailed geological mapping, likely involving hydraulic clearing of outcrop, is part of the site selection and site characterization process ... This impact on soil is not mentioned in R-Preclosure. [Comment 487, Source Document tec004, Page 151, Section D-2.2.5]

OPG RESPONSE

Site characterisation activities at a preferred site will include detailed geologic mapping of exposed bedrock outcrops. Dependent on the degree of bedrock exposure, it may be required that a thin (1m) veneer of soil be remove to expose the underlying bedrock surface. Examples of such practices include surface fracture mapping activities at the East Bull Lake and Atikokan research areas, as well as, at the Chalk River Laboratories Flow System Study Area. Typically, exposed surface areas for such mapping studies are less than 0.5 to 1 ha. Locations at which outcrop clearing may occur are remote and unable to support and/or sustain agricultural development. Mitigating measures to avoid increased soil erosion and surface water sediment loading would be implemented, if site specific conditions dictated.

4.01.02 System Performance - Activities - Off-Site Activities

PARTICIPANT COMMENTS

Scientific Review Group

The cumulative impacts of off-site activities, such as the mining of bentonite or the management facility for low- and intermediate-level radioactive wastes generated from disposal facility activities, should have been considered as well. [Comment 476, Source Document tec004, Page 096, Section 7.7]

OPG RESPONSE

The EIS and the supporting documentation (e.g., "The Disposal of Canada's Nuclear Fuel Waste: Preclosure Assessment of a Conceptual System") recognise that there will be off-site impacts from the construction and operation of a geologic repository facility for used fuel since resources such as bentonite clay, glacial lake clay, sand and other engineered barriers materials will have to be obtained elsewhere, processed and transported to the facility. Low and short-lived intermediate-level radioactive wastes are assumed to be transported to a facility to manage low and short-lived intermediate-level radioactive wastes, and their impacts would be addressed by the facility which manages these wastes.

4.01.03 System Performance - Activities - Blasting

PARTICIPANT COMMENTS

Campaign for Nuclear Phaseout

The EIS indicates that explosives will be used in the creation of the repository. There is no discussion of the potential for accidental explosion and effect on the fuel waste [Comment 1791, Source Document pub027, Page 23, Section III.C]

Mouvement Vert - Mauricie

The proponent plans to continue excavating the site, probably using the drill and blast technique, during the operational phase of the underground repository. No management plan for explosives has been presented and the site layout indicates no specific storage location for explosives. How will the proponent ensure the safety of irradiated fuel with explosives on the site? What type of accidents (including both human error and criminal acts) could arise that involve explosives and nuclear fuel waste? What mitigating measures can minimize this risk? What emergency measures would be necessary to respond to an explosion in the vaults or in proximity to the above-ground storage modules? [Comment 1495, Source Document pub024, Page 33, Section 2.4.7]

Northwatch

the EIS should discuss the potential for accidental explosion and effect on the fuel waste [Comment 1376, Source Document pub046, Page 15, Section d]

OPG RESPONSE

The EIS support document, "The Disposal of Canada's Nuclear Fuel Waste: Engineering for a Disposal Facility", discusses the control of hazardous material including detonators and explosives. These items would be stored separately on the surface in approved buildings or magazines at the geologic repository facility. The quantity in storage at any time would depend on the rate of use, the distance to the suppliers and the size of the shipment. The requirements for the safe storage and handling of explosives and detonators, and many other hazardous materials used in mining operations, are set out in legislation such as the "Regulations for Mines and Mining Plants" by the Government of Ontario. OPG believes that the potential for accidental explosion near nuclear fuel wastes is small and has been bounded by other accident scenarios discussed in the EIS and supporting documentation.

As described in "The Disposal of Canada's Nuclear Fuel Waste: Engineering for a Disposal Facility", the nuclear fuel waste container transportation and emplacement operations, and the explosives handling and construction activities would be widely separated within the repository. The distances would be sufficient that the construction activities would not affect in any way the containers or the emplacement operations. As an example, in AECL's URL, tunnel construction blasting was done along a straight tunnel within about 100 m of the instrumentation control room of the Buffer/Container Experiment, while the experiment was operating. The bulkheads constructed in the tunnel dissipated the bulk of the blast percussion and energy and the experiment operation continued uninterrupted. In the repository the separation would be many 100s of metres, there would be curves in the tunnels and ventilation/access control bulkheads separating the emplacement and construction operations.

4.01.04 System Performance - Activities - Alteration of Baseline Conditions

PARTICIPANT COMMENTS

Canadian Voice of Women for Peace

the preclosure activities produce considerable risks and furthermore alter the very conditions on which the computer based predictions of environmental effects are based [Comment 1916, Source Document cs023, Page 2]

Northwatch

the EIS should discuss the results of site disturbance in the process of site characterization; this should include a discussion of investigative disturbance resulting in a loss of site integrity [Comment 1387, Source Document pub046, Page 17, Section d]

OPG RESPONSE

The EIS support document, "The Disposal of Canada's Nuclear Fuel Waste: Preclosure Assessment of a Conceptual System", recognises that the preclosure activities will have a small but measurable effect on humans and the natural environment, and has recommended activities to mitigate these impacts. The preclosure assessment models take into account the environmental effects from preclosure activities. The projected risks and impacts from preclosure activities associated with a real deep geologic repository facility at a real site will be addressed in the environmental assessment and licensing processes for the facility. In the meantime, valuable operating experience has been gained from the operation of underground laboratories in crystalline rock (e.g., URL in Canada, Aspo in Sweden).

4.02

4.02.01 System Performance - General - Breaches of Security

PARTICIPANT COMMENTS

Scientific Review Group

Security measures are an important component of safety management, but the possible consequences of sabotage, hijacking of truck cargo, insurrection and terrorism are not addressed [Comment 103, Source Document tec004, Page 146, Section D-2.1.7]

OPG RESPONSE

Security measures and responses to threats would be discussed with the regulator at the time of implementation. See also response to category 2.16.

4.02.02 System Performance - General - Rock Bursts

PARTICIPANT COMMENTS

Scientific Review Group

The conclusion that "... there is no realistic probability of significant rock-burst risk associated ... with the creation and utilisation of a functional repository in the same type of environment ... (as the Underground Research Laboratory)" (R-Facility 1994: p.130) can only be treated as an unsubstantiated assertion, and not as a scientific conclusion. [Comment 94, Source Document tec004, Page 139, Section C-2.2.2]

the potential for some accidents, rock bursts and other implications for worker safety should have been further investigated. [Comment 131, Source Document tec004, Page 151, Section D-3]

OPG RESPONSE

The response of rock to underground excavations in highly-stress rock of the Canadian Shield has been extensively studied at the Underground Research Laboratory (URL) near Lac du Bonnet, Manitoba (e.g., Mine-By Experiment, Excavation Stability Studies) (see Read and Chandler 2002). Rock burst is sensitive to the shape of the underground excavation, the method used to create the excavation and the stress in the rock, and thus the openings can be designed and engineered to minimise the risk of rock burst. Experience gained by operation of the URL has indicated that significant rock burst is not probable and that only localised, small-scale strain bursts of rock slabs are likely to occur at an underground repository for nuclear fuel wastes on the Canadian Shield.

Reference:

Read, R.S. and N. A. Chandler. 2002. An approach to excavation design for a nuclear fuel waste repository - the thermal mechanical stability study final report. Prepared by RSRead Consulting Inc. and Atomic Energy of Canada Limited. Ontario Power Generation, Nuclear Waste Management Division Report 06189-REP-01200-10086-R01.

4.02.03 System Performance - General - Vault as Exploration Target

PARTICIPANT COMMENTS

Scientific Review Group

the amount of metal in the waste disposal containers may be large enough to make the contents of the vault a future target for resource exploration [Comment 346, Source Document tec004, Page 045, Section 6.2.1]

OPG RESPONSE

OPG recognises that the geologic repository may contain materials that may be of value to a future society. This feature was considered in the assessment of inadvertent human intrusion into the repository (see Wuschke 1996, AECL Report AECL-10279 Rev. 1).

4.02.04 System Performance - General - Health Effects of Radiation PARTICIPANT COMMENTS

Campaign for Nuclear Phaseout

A fuller exposition on the biological impact of nuclear waste is required ... include an independent and comprehensive evaluation of the impact of radiation from high level waste which would include an analysis on the basis of occupation (ie. worker/ member of public), gender and age.... include an examination of evidence pointing to increases in uterine, thyroid and breast cancers in women exposed to radiological sources. The impact of radiation on children of varying ages must also be reviewed. [Comment 1777, Source Document pub027, Page 04, Section II]

The EIS should contain a discussion of both fatal and non-fatal effects of exposure to nuclear waste radiation and materials. [Comment 1778, Source Document pub027, Page 05, Section II]

The EIS fails to provide information about the effects of low-level radiation from nuclear waste related processes on living organisms.... Links between low level radiation exposure and teratogenic effects (environmentally induced mutations during fetal development) which have been documented in reports and studies undertaken by the U.S. Department of Energy, UNSCEAR (United Nations Scientific Committee on the Effects of Atomic Radiation) and BEIR (U.S. National Academy of Sciences Committee on the Biological Effects of Ionizing Radiation), among others, are not discussed in the EIS. [Comment 1817, Source Document pub027, Page 32, Section III.H]

Canadian Coalition for Ecology, Ethics and Religion

the health effects of ionizing radiation, as presented in the EIS, were not given a full and balanced treatment. [Comment 1836, Source Document phpub043, Page 27, Section 11]

Canadian Coalition for Nuclear Responsibility (Regroupement pour la surveillance du nucléaire)

[Discuss] the entire range of radiation-induced effects in human beings and in non-human biota, with special attention to those of long-term significance.... particulate versus non-particulate radiation ... potentially significant effects of radiation ... radiation dose and relative biological effectiveness (RBE) ... threshold versus non-threshold effects of radiation ... stages of acute radiation sickness [Comment 1876, Source Document pub049, Page 21]

include a thorough discussion of radiation-induced cancers and genetic effects ... which cancers are considered "fatal" and which are considered "non-fatal" ... a discussion of non-fatal cancers ... a matching between cancer sites and various radionuclides ... an explanation that radiation-induced cancers and genetic effects ... depend on the population dose ... an operational definition of genetic effects ... the number of generations considered to be at risk by a "serious genetic effect" ... the potential long term effects, both qualitative and quantitative, of damaged recessive genes ... the potential long term implications of increased impairment of human and non-human intelligence ... the types of possible genetic effects of complex etiology and their potential significance [Comment 1883, Source Document pub049, Page 22]

[Include] a qualitative and quantitative discussion of the long-term consequences of radiation-induced genetic effects in birds, fish, mammals, insects, and plants [Comment 1884, Source Document pub049, Page 22]

A complete list of radionuclides in the irradiated fuel and the zirconium cladding should be given ... together with the most significant physical, biological and ecological features of each one, such as

- the type of radiation emitted together with energy levels and half-life;
- whether it is a fissionable or fissile radionuclide;
- its principal decay chain(s);
- critical organs and retention times;
- maximum permissible body burden;
- maximum permissible concentration in drinking water;
- relative importance of ... routes of exposure;
- potential for bioconcentration and/or biomagnification ...
- relative degree of scientific knowledge of the specific biomedical and bioecological properties ...
- any particular biological concern(s) [Comment 1887, Source Document pub049, Page 25]

Ecosystem Approach Group

How come AECL does not want to know the [radiation] effect on DNA, which is known? [Comment 2030, Source Document pub033, Page 03]

Health Canada

The EIS contains minimal discussion on radiological health effects, including the types of effects or cancers, or the uncertainties in radiological risk coefficients at low levels of exposure.... effects other than cancer should be addressed in terms of epidemiological studies that either contest or support the existence of such effects ... It would be helpful to include a scale of doses that illustrates the dose and risk associated with various levels of stochastic and deterministic exposure, the doses associated with the various Canadian and international regulations and guidelines, and the exposure levels from natural background radiation. [Comment 2143, Source Document gov006, Page 03]

More material should be presented on the effects of ionizing radiation in humans, particularly on those studies that have purported to see effects at doses approaching background values. The relevance or irrelevance of these studies should be discussed. The possibility of effects other than cancer or genetic disorders should also be discussed. [Comment 961, Source Document gov006, Page 17]

Mouvement Vert - Mauricie

AECL does not describe the different effects [on human health] of the various fission and activation products contained in the fuel bundles.... The MVM would particularly like to know the likelihood of contracting fatal cancer or any non-life-threatening anomaly following exposure to, or injestion or inhalation of, varying quantities of irradiated fuel, based on the age of the fuel. A set of scenarios should be formulated, both likely and unlikely, that can help explain above-normal levels of exposure. [Comment 1486, Source Document pub024, Page 25, Section 2.4.1]

National Action Committee on the Status of Women

the EIS does not address the potential impacts of radiation on women's health [Comment 1934, Source Document pub026, Page 23, Section 7.2]

In section 8.3 of the Guidelines it is made clear that the discussion of potential health effects should not be restricted to mortality.... the EIS is deficient in this regard. Both the EIS and the standards it refers to focus solely on mortality risks of radiation exposure as opposed to increased morbidity. This is disturbing given that many non-fatal conditions and diseases are linked to radiation exposure, and many of these conditions are specific to women. [Comment 1283, Source Document pub026, Page 27, Section 7.2.5]

National Council of Women of Canada

NCWC is dismayed to note that absolutely no mention is made of the fact that women, and their children before and after birth are particularly vulnerable to the hazards of radiation, particularly in the event of an accident. [Comment 1321, Source Document phpub035, Page 04]

Northwatch

the description of nuclear fuel waste should include a description of characteristics of nuclear fuel waste, and its chemical and radiological properties and their effect on human and other natural systems; the description should describe the effect or impact of each radioactive and chemical element, and the description should be specific and detailed, eg. identifying pathways and affinities of various elements with various organs or functions (this is particularly with respect to the human system, but should not be limited to the human system); the discussion should be linked to a discussion of various impacts, including fatalities, fetal stress, retardation, reproduction, immune deficiencies, etc. [Comment 1357, Source Document pub046, Page 08, Section d]

the EIS does not describe the effects of the continued activity of the long lived fission products [Comment 1394, Source Document pub046, Page 19, Section d]

the EIS does not ... discuss the potential human health impacts of radiation, radionuclides and other contaminants on humans and various components of the natural environment in the short and long term (pg.51) [Comment 1395, Source Document pub046, Page 20, Section d]

Northwatch (Willis)

In its documentation AECL provides only a generic characterisation of the nuclear waste which is to be buried.... The specific character of radiotoxic elements, once they enter the human environment and the human body, is virtually unremarked. The analysis refers to whole-body doses without reference to, for example the possible inhalation of alpha-emitters. It is assumed in AECL's analysis that all fuel bundles are identical in terms of radioactive and toxic contaminants, heat generation, shape, and the time it has been stored in pools before being buried. [Comment 1564, Source Document ph3pub096a, Page 06, Section 4]

Nuclear Awareness Project

[Describe] each radioactive element found in used nuclear fuel (fuel from both commercial and research reactors) and in reprocessed fuel waste in terms of

- the proportion of the total waste that each element makes up over time ...

- the specific impact of each radioactive element on humans and other species [Comment 1605, Source Document pub035, Page 4, Section B]

[Describe] the expected human health impacts of a range of mishaps and accidents ... for the implementation stage of the vault and the post-decommissioning stage of the vault, including ... the expected rates of occurrence of diseases including specific cancer incidence rate (thyroid, leukaemia, etc.), rates for a wide range of major and minor birth defects, and other health impacts [Comment 1938, Source Document pub035, Page 4, Section B]

Saskatchewan Environmental Society

there is no acknowledgement in the EIS that the total number of cancers for a particular organ will be proportional to the total exposure of that organ among the entire population of workers at the site and among the entire population surrounding the nuclear waste disposal facility. [Comment 1667, Source Document pub040, Page 06, Section 11]

There is virtually no discussion of the relationship between exposure to ionizing radiation and health problems in subsequent generations such as stunted infant growth, higher infant mortality, Downs Syndrome, a higher frequency of spontaneous abortions, a higher frequency of mental retardation and a higher frequency of heart disease. [Comment 1668, Source Document pub040, Page 06, Section 11]

There has been no attempt by AECL to discuss the state of knowledge of each radionuclide in used Candu fuel and its potential health and environmental impacts if it is released into the biosphere. [Comment 1669, Source Document pub040, Page 06, Section 11]

United Church of Canada

the hazardous nature of the waste, its radiotoxicity and chemical toxicity and the biological effects of the radiation and chemically toxic substances are not adequately presented ... Not just fatal cancers and serious genetic diseases, but other illness as well may result from the increasing background radiation level and multiple exposures which humans and other life forms experience in addition to that background. [Comment 1742, Source Document phpub124, Page 3-19, Section 3]

OPG RESPONSE

OPG believes that current methodology and data for estimating radiation effects are conservative and suitable for assessing potential impacts throughout the life cycle of a deep geologic repository. It is recognised that although standard methodology is to add the effects of all radionuclides, taking account of their radiation characteristics (thus accounting for all and for cumulative effects of all), there is interest in a discussion of each radionuclide and its effects. It is expected that at a future EA or development stage, a full discussion of the effects of radiation could take place. Some points noted for this discussion are:

impacts for different genders and ages fatal and non-fatal cancer teratogeny other effects other than cancer effects on DNA particulates vs. non-particulates (form of radionuclide) RBE effects of different radionuclides - characteristics, state of knowledge, special effects epidemiology, especially at low dose levels scale of doses - acute doses.

The discussion should focus on what are the expected impacts of this facility, e.g. acute radiation sickness is not an expected impact, although it might be discussed as part of a comprehensive picture

. The high cost of the deep geologic repository is spent to put the used fuel in a location such that any eventual release from the waste container is contained, retarded, delayed, adsorbed and diluted, resulting in very small, if any, release to the biosphere.

4.02.05 System Performance - General - Thermal Effects

PARTICIPANT COMMENTS

Atomic Energy Control Board

The diverse thermal analyses used to predict the evolution of the temperature distribution in the repository are not performed, evaluated and presented consistently and are not shown to be either realistic or conservative. The accuracy and precision of the results do not justify the use of several significant figures in the "simplified" temperature calculations and corresponding corrosion rates in the postclosure assessment using SYVAC. [Comment 619, Source Document gov002, Page 47, Section C.1.3(iv)]

Campaign for Nuclear Phaseout

the effects of heat (from the fuel waste) during the operating/filling period [are not] examined. [Comment 1792, Source Document pub027, Page 23, Section III.C]

A discussion of heat effects in the EIS should include: thermal pulse, and its effect on the rock mass; heat on rocks resulting in steam/vaporization; local climate change; effect of steam on containers; effect of heat on bentonite; effect of heating water creating eddies and circulation of water in the rock form (exchange of heated and unheated water, in the effort to establish a natural equilibrium). [Comment 1801, Source Document pub027, Page 25, Section III.E]

Canadian Coalition for Nuclear Responsibility (Regroupement pour la surveillance du nucléaire)

The expansion and contraction of the subterranean rocks due to the heat produced by buried radioactive wastes will affect the repository for fifty thousand years or more. [Comment 1902, Source Document ph3pub188, Page 2]

Chemical Institute of Canada

Temperature gradients are set-up in the disposal area compared with the surroundings (80 deg. C compared with 17 deg. C). Will not the consequent density gradients in the ground water create conditions for more rapid circulation and flow rates than those indicated? [Comment 1127, Source Document tec005, Page 23, Section IV.i.2]

Conservation Council of New Brunswick

the expansion and contraction of the subterranean rocks due to the heat produced by buried radioactive wastes will affect the repository for fifty thousand years or more. [Comment 1990, Source Document ph3pub162, Page 2]

Environment Canada

there is also concern about the absence of any quantitative assessment of thermal effects on radionuclide transport in the vault (particularly in light of the potential for transport through the excavation damage zone) [Comment 853, Source Document gov003, Page 20, Section 2.9]

Kenora Committee Against Nuclear Waste

The placing of any nuclear fuel waste at the depths being suggested by the proponents ... will create a gradual increase in the temperature in the depository. Heat will be radiating out in all directions but being hotter on the lower side due to the fact that the deeper rock will be warmer and the nuclear waste will be further heated by the heating up of the granite at the base of the "depository".... The result of this would result in changes in the forces of the immediate walls of granite, leading to a more rapid crushing of such chambers. [Comment 2127, Source Document ph3pub063a, Page 33]

There will be cracking in the pluton due to the heat differentials created by the depository. The cracking of the pluton will eventually lead to infiltration of water, this becomes a danger when the temperature is high enough to create steam, to complicate matters the build up of gas pressure will add to the force whether the water reaches steam temperature or not. It will seek any crack or crevice leading to the surface and can appear at the least, as radioactive hot springs and/or as a geyser. The more serious result would be of an explosive nature and could be described as a man made radioactive volcano. [Comment 2129, Source Document ph3pub063a, Page 35]

Northwatch

the EIS should include, in its discussion of the effect of heat (from the fuel bundles) in the repository, the following effects and concerns: thermal pulse, and its effect on the rock mass; heat on rocks resulting in steam/vaporization; local climate change; effect of steam on containers; effect of heat on bentonite; effect of heating of water and its creation of eddies and water circulation patterns in the rock mass [Comment 1363, Source Document pub046, Page 13, Section d]

the EIS should discuss heat generated from the fuel waste during the period of operation, and its effect on worker safety, vault integrity, and facility operations [Comment 1377, Source Document pub046, Page 15, Section d]

People Against Nuclear Energy

The third reason we cannot bury nuclear waste is because of heat.... We have no idea to what extent this mass could heat up and what destruction it could create. [Comment 1644, Source Document ph3pub165, Page 2]

Scientific Review Group

the long-term effects of the heat generated by the fuel waste should not be neglected, because the integrity of the WEZ cannot be assured.... If the thickness of the WEZ were less than the required minimum, the effect of the heat source might become significant, because the time scales of heat transport and contaminant transport could be similar. [Comment 375, Source Document tec004, Page 056, Section 6.3.1]

There is no discussion as to how the thermal field might be used to map deep groundwater flow regimes (R-Siting 1994: p.99).... AECL has considered the perturbation of the ambient temperature field due to the waste-generated heat to be slight, but the review of the R-Geosphere ... revealed that this assumption holds only for certain specific conditions that may not be satisfied. [Comment 7, Source Document tec004, Page 107, Section A-2.1.4]

The document does not adequately describe the consequences of higher temperatures in the vault stemming from greater than cited fuel burn-up values, or address the issue that adequate measures can be taken to ensure that temperatures can be maintained at the desired levels... If increased container spacing is a possible mitigation measure, the effects of increased spacing on the stability of the vault, the vault size, and cost of construction, should have been taken into consideration [Comment 31, Source Document tec004, Page 120, Section B-2.1.3]

The reference in-borehole container emplacement design may result in ambient temperatures up to 120 C, that exceed the limiting design temperature constraint... especially for the case of containers containing used fuel bundles which may exhibit higher than average burn-up rates. [Comment 96, Source Document tec004, Page 140, Section C-2.2.4]

The list of factors that were dismissed from further analysis includes ... temperature gradients.... Temperature gradients due to buoyancy were found to be negligible ... only if the WEZ is at least 50m thick. [Comment 488, Source Document tec004, Page 170, Section E-2.1.4] Heat dissipation may be slower than anticipated, and maximum temperatures in the disposal vault may be higher.... the rates of heat dissipation by conduction may be less than predicted, and maximum temperatures may be higher, if an unsaturated condition exists. Therefore, because of these uncertainties in heat dissipation, combined with the lack of realistic modelling tools and in situ test data, it is not clear that temperatures below 100 C can be sustained for unsaturated conditions.... There is a lack of either deterministic modelling or multiple container model tests.... At present, steam formation is ignored ... If the temperature in the vault exceeds 100 C, cracking of buffer and backfill material and increased gas pressures may develop. This could result in a more rapid release and transport of radionuclides. [Comment 217, Source Document tec004, Page 200, Section F-2.1.3]

Possible impacts of higher temperatures over longer time periods, of steam production, of gas production from microbial activities, of radiolysis, etc. on the buffer and backfill material should have been clarified, given the critical role of clay-based barriers in radionuclide containment. [Comment 218, Source Document tec004, Page 201, Section F-2.1.3]

The conclusion (R-Geosphere 1994: p.167) that heat generated from the waste in the vault would have only minor effects on groundwater flow paths and travel times may be unjustified... Careful loading of canisters may be required to avoid higher than expected container surface temperatures; and reliable data on nuclear fission yields are required to forecast heat output. [Comment 251, Source Document tec004, Page 222, Section G-3.2.17]

OPG RESPONSE

For the EIS, thermal analyses were conducted with analytical model, with AECL's HOTROK (analytic) and MOTIF (finite element) codes, and by Ontario Hydro and Golder Associates (using finite element codes). The potential thermal effects on container materials, sealing materials (buffer, backfill, etc.), rock properties, groundwater flow and contaminant transport were also considered as described in AECL's EIS (AECL 1994) and supporting documentation, and were factored into the vault layout design and safety assessment. (For example, maximum groundwater velocities from thermal heating were assumed for the safety analyses). These analyses are considered to be conservative. Additional independent thermal analyses of a deep geologic repository are being conducted by consultants in 2003 using commercial codes PATRAN and ABAQUS to update the conceptual design of a repository on the Canadian Shield. The initial results are similar to the previous conservative thermal analyses. The report will be issued in 2003.

The major temperature limit established for the repository facility is 100 C or less on the outer wall of the container. The thermal analyses indicate that this temperature limit can be satisfied by spacing the containers of used fuel appropriately in the repository, and by controlling the used fuel bundle burnup and age as placed into each container. For example, recent analyses of conceptual repository designs have assumed that all fuel bundles are average burnup and 30-years old. (A recent analysis also did sensitivity cases using the 95th percentile of the burnup distribution (Baumgartner and Ates. 2001). In fact, it is likely that the average age of fuel will be much older (and therefore cooler) by the actual time of emplacement. Also, since the thermal power of a used fuel bundle is determined by beta/gamma decay during the peak temperature period, it should be straightforward to independently check the thermal power of used fuel containers at the packaging plant, if necessary, by using gamma radiation detectors.

In 2000, OPG reviewed the treatment of thermal effects in a repository and found that the potential effects are reasonably understood and conservatively treated. Further thermal analyses of a hypothetical deep geologic repository in plutonic rock are planned to confirm the previous analyses and to provide a more detailed and realistic estimate of the thermal history of a repository for engineering and safety analyses.

If a deep geologic repository is the approach selected for the long-term management of Canada's used fuel, additional analyses would be done to further advance and optimise the design of a repository.

Reference:

Baumgartner, P. and Y. Ates. 2001. Packaging plant and repository factors affecting the selection of preferred used-fuel container geometries and capacities. Prepared by Atomic Energy of Canada Limited. Ontario Power Generation, Nuclear Waste Management Division Report 06819-REP-01200-10064-R00. Toronto, Ontario.

4.02.06 System Performance - General - Microbes

4.02.06.01 System Performance - General - Microbes - General

PARTICIPANT COMMENTS

Campaign for Nuclear Phaseout

A more detailed description of how the movement of microbes would be constrained is required ... examine the issue of microbial action and corrosion in all of the system, containment and vault models described in the EIS. [Comment 1795, Source Document pub027, Page 24, Section III.E]

Environment Canada

AECL ... have not accounted for the possible effects of microbial processes on fuel leaching (e.g. the effects of microbes on the volatilization of{14}C or {129}I, or mobility of {99}Tc and {238}U by microbial metabolic activity). More research on these aspects is necessary prior to final repository design. [Comment 864, Source Document gov003, Page 23, Section 2.11]

Joint Committee of the Canadian Academy of Engineering and the Royal Society of Canada

We note the SRG concerns that; "the essentially continuous network of microbial activity from deep within the geosphere to the surface is ignored." More research may be required on the possible role of living organisms in the transfer of contaminants. [Comment 1158, Source Document ph2tec007, Page 05]

Natural Resources Canada

The discussions of microbiological issues are generally inconclusive. The EIS says very little about the present state of knowledge of microbes at depth. It does not, as required by the guidelines, explain the relative importance of indigenous or introduced organisms. It avoids this type of examination and analysis of microbially modified corrosion of containers by suggesting that the small pore size of the filler materials would constrain microbial mobility. [Comment 707, Source Document gov005, Page 11, Section 5.4]

Scientific Review Group

the position is taken by AECL that ... microbial processes do not need to be considered explicitly. This approach and conclusion appears to the SRG to be unwarranted without more evidence or discussion.... To what extent microbes can be managed or encouraged through the design of the depository and the materials used to retard movement of contaminants and protect the surface ecosystem and humans is uncertain. These are issues that appear to be important to a long-term generic waste disposal concept; but these issues are not addressed through BIOTRAC or any of the associated models. [Comment 393, Source Document tec004, Page 063, Section 6.4.2]

an acceptable disposal facility design from point of view of microbiological considerations can be implemented with additional laboratory and pilot scale evaluations of the potential impact of the subsurface biosphere and the microbial components of the surface biosphere on the integrity of the disposal concept. [Comment 300, Source Document tec004, Page 240, Section I-S]

Microorganisms pass through a life cycle ... not necessarily of short duration. Some laboratory experiments may be too short in duration to encompass the complete cycle effectively. A common aspect of microbial activity is trauma in an alien environment (e.g. when subjected to laboratory experiment). Therefore, there is a distinct possibility that the microbial community would not function in a manner that would typically occur under natural conditions in the fullness of time. [Comment 308, Source Document tec004, Page 243, Section I-2.5]

By the application of ... sterile conditions as one part of an experiment, the exact importance of the physico-chemical factors can be divorced from interference from the active living microorganisms which would otherwise be present. This knowledge would allow a better prediction of the likely pathways and rates of radionuclides and other contaminants to the surface via the geosphere where a containment system had been significantly compromised. [Comment 316, Source Document tec004, Page 246, Section I-2.10]

there is still the need at the conceptual level for an examination of the degree of stimulation of microbial activities as a result of changes in the impacted environment due to intrusions resulting from the installation of the disposal vault. [Comment 525, Source Document tec004a, Page 12, Section 2.6]

the potential role of the subsurface biosphere in the bioaccumulation, retention and transport of radionuclide needs further examination at the conceptual level. [Comment 526, Source Document tec004a, Page 12, Section 2.6]

OPG RESPONSE

In the 1990's, there has been a substantial increase in the information available on microbes in deep rock suitable for used fuel disposal, in part as a result of research at underground laboratories around the world, including the Canadian URL facility in Pinawa, Manitoba. Recent general summaries of the microbial populations and activities are given in West et al. (2001), Stroes-Gascoyne and West (1996a) and Pedersen (2000).

Significant Canadian studies of microbes include:

- microbial analysis of various boreholes in the Canadian Shield (Haveman et al 1995);

- the 2.5-year in-rock Buffer/Container Experiment, including studies of the effect of hot canisters on the microbes (Stroes-Gascoyne et al, 1996b);

- the 7-year in-rock Isothermal Test, including measurements of microbe activity in buffer and on interfaces (Stroes-Gascoyne et al 2000);

- laboratory studies of microbial-related corrosion and gas-generation (Ogundele and Jain 1999).

- in-situ studies of biofilm formation and effectiveness for radionuclide sorption.

Microbial-related research is continuing in Canada and elsewhere. The general conclusion of these studies is that microbes will be present around the repository, and that they should be considered in both the design and the safety assessment of any proposed repository. For example, the engineering/operation design should minimize the amount of organic nutrients left underground, and the buffer density should be sufficiently high to inhibit microbes. However, with due consideration such as these and others, we believe that microbes will not compromise the safety of a repository.

The influence of microbes on system performance is formally identified in the OPG FEP Database, and so will be specifically considered in any future safety assessment. A recent example is the OPG Third Case Study, especially in the FEP report (Garisto et al. in prep.) and Base Scenario report. (McMurry et al. 2003).

REFERENCES

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4.02.06.02 System Performance - General - Microbes - Nutrients PARTICIPANT COMMENTS

Environment Canada

The properties of the backfill are adequately described except for the amount, type, and effects of the organic matter contained within the lake clays. This is particularly important from the perspective of the generation of gas within the repository by microbes. It should also be considered given the potential influence that microbes could have on the retardation of nuclides. [Comment 841, Source Document gov003, Page 13, Section 2.4]

Natural Resources Canada

The possibility of significant amounts of organic carbon being introduced into the vault with the buffer and backfill material appears not to have been considered. The presence of carbon may support microbial activity that can influence metal corrosion. [Comment 760, Source Document ph2gov001, Page bar6]

Scientific Review Group

no quantitative figures for microbial action are given, and there is no mass balance of the nutrients that could give an indication of the likely scale or duration of microbiological activity. Without such information or evidence, the statement that microbial action can be dismissed as insignificant appears unwarranted. [Comment 395, Source Document tec004, Page 064, Section 6.4.2]

Essentially, microbiological challenges to the engineered barriers are dismissed.... The organic carbon content of deep granitic rock is low. However, carbon may be introduced to the vault as a result of excavation, emplacement and sealing activities. Blasting is likely to introduce carbonaceous and nitrogenous compounds into the vault and its environs. These compounds may become a source of nutrients for microbial activity. A mass balance should have been presented for all potential nutrients. [Comment 34, Source Document tec004, Page 121, Section B-2.1.7]

the various engineering activities ... would almost certainly directly and indirectly cause an increase in nutrient loadings to the vault environment.... there is a significant potential for nitrogen and, to a lesser extent, organic carbon (as hydrocarbons) to enter the vault system during the drill and blast operations.... the possible impact of using internal combustion engines within the vault could lead to further nutrient sources, including condensed exhaust gases and spilt oils, becoming resident in the vault. Human activities may also add to the nutrient load through unhygienic practices of convenience. A mass balance for all nutrients likely to become resident within the vault environment, and clarification of the potential for the buffer and backfill to also provide nutrients and substrates for microbial activities, should have been developed.... Shifts in the hydrologic flow conditions around the vault may also cause nutrient inputs from the surrounding groundwaters if, and when, the seals emplaced during the activity cycle of the vault fail for whatever reason. [Comment 313, Source Document tec004, Page 244, Section I-2.7]

The container loading and sealing is proposed to be performed at the disposal site facility. This would involve a large number of workers and ancillary activities in close proximity to the disposal vault. Such activities would clearly increase the potential for surface waters, nutrients and associated wastes to penetrate into the subsurface environment. The potential for this to occur should have been assessed. [Comment 317, Source Document tec004, Page 246, Section I-2.11]

OPG RESPONSE

An inventory of bacterial nutrients that would be placed 'intentionally' with vault materials (fuel waste, waste containers, buffer and backfill materials) has been provided in Stroes-Gascoyne (1989). This report concluded that N would then be the growth-limiting nutrients, and made conservative estimates

for the possible microbial population.

A subsequent report (Stroes-Gascoyne et al. 1996) assesses bacterial nutrients that would be added 'inadvertently' to a vault in the form of residues of materials used to excavate and operate a vault. This assessment was based on measurements of residues in the various water supplies, excavated broken rock and tunnel wall cores that were made at AECL's Underground Research Laboratory, plus estimates of other materials such as grease, paints and oils. These results show that the largest potential inadvertent nutrient addition (both carbon and nitrogen) to a vault would result from using untreated excavated broken rock as part of the backfill.

As part of a future site specific design or safety assessment, the microbial analysis can use this information to judge the importance of these nutrient sources at that specific site. If nutrients might be important, then design options include using nitrate-free groundwater to prepare buffer and backfill, to allow broken rock to be exposed on the surface before use as backfill (so that nitrates and organics are removed naturally), and to ensure that wood beams are removed during decommissioning.

REFERENCES

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S. Stroes-Gascoyne. 1989. The potential for microbial life in a Canadian high level fuel waste disposal vault: a nutrient and energy source analysis. Atomic Energy of Canada Limited Report, AECL-9574.

4.02.06.03 System Performance - General - Microbes - Mutagenesis

PARTICIPANT COMMENTS

Canadian Coalition for Nuclear Responsibility (Regroupement pour la surveillance du nucléaire)

[Include] an informed discussion of the possibility that microbes in the vault may adapt under mutagenesis to exploit the new materials introduced into the vault, including some of the radionuclides themselves, and the effects this might have on the dissolution of the waste form and the transport of contaminants [Comment 1885, Source Document pub049, Page 22]

[Include] an informed discussion of the possibility that radiation-induced mutagenesis in microbes or their vectors over very long time periods may lead to new strains of disease to adversely affect human and/or non-human populations. [Comment 1886, Source Document pub049, Page 22]

Chemical Institute of Canada

There is naturally occurring microbial life present in ground water but the ecology is poorly understood and it is not known whether such life exists at the depths suggested for storage. Would such organisms be affected by the radiation and even if the radioactive materials are not released in toxic quantities, will affected microorganisms that are present move to the surface and interact with the surface biosphere? Microorganisms will also be introduced with backfill. Could these organisms be affected and find their way back to the surface? [Comment 1130, Source Document tec005, Page 24, Section IV.i.5]

Scientific Review Group

microbial processes could, over time, themselves be changed by the presence of ionizing radiation and in turn could affect transport of radionuclides and other contaminants by such mechanisms as change in redox potential and bioavailability. [Comment 261, Source Document tec004, Page 230, Section H-2.2]

OPG RESPONSE

There is ongoing research to better understand microbial activity in a repository. OPG will continue to support and monitor developments, and provide reports on microbes and their expected behavior in a Canadian disposal vault. However, some arguments are presented below to indicate why mutation in particular is not likely to be significant:

1. It is clear that there are already diverse microbial species at the depths and geological conditions of interest for used fuel disposal. The added clay/backfill materials themselves will also include natural microbes. The different species are adapted to a wide range of energy sources and conditions. Since the native species already span a variety of niches, the presence of a vault will likely affect which species prosper (and at which time) rather than fostering the creation of substantively different species by mutagenesis or natural evolution.

2. Microbial species at depth tend to be different from those in surface biosphere. There is also evidence that placing surface microbes into vault conditions results in death of the surface species. Furthermore, humans have already been exposed to underground microbial populations as a result of activities such as mining and oil extraction, without any new diseases related to these activities. Therefore, the microbial adaptations for conditions deep underground do not appear to be relevant to human pathology.

3. While the radioactivity in a repository is significant, it is a tiny fraction of the natural background radioactivity present around the world. If simple mutation of some underground microbial species could result in some significant new species formed, it is more likely to occur (or already have

occurred) in the bulk geosphere.

4. The buffer material in the immediate vicinity of the containers will have low water activity, small pore spaces, and diffusion-limited transport of nutrients or metabolites, all fundamental factors that will restrict the growth and movement of microbes. (Irradiation tests with native buffer microbial populations indicates that they are killed by the combination of heat and radiation fields anticipated at the surface of the EIS containers (Lucht and Stroes-Gascoyne 1996). However, current container designs have much lower radiation fields.)

References

L.M. Lucht and S. Stroes-Gascoyne. 1996. Characterization of the radiation and heat resistance of the natural microbial population in buffer materials and selected pure cultures. AECL TR-744, COG-96-171. Pinawa, Manitoba.

4.02.06.04 System Performance - General - Microbes - In the Vault PARTICIPANT COMMENTS

Environment Canada

gas generation within the vault ... needs further analysis, especially the potential for microbially generated gas.... Microbes may produce gas from processes such as biodegradation of organic matter in the vault (e.g. glacial lake clays) and container or other metal corrosion. The presence of gas in the vault may also support other microbial populations in the vault. [Comment 867, Source Document gov003, Page 24, Section 2.12]

Mouvement Vert - Mauricie

the effect of microbial activity on the rate of corrosion of the shell has not been addressed [Comment 1490, Source Document pub024, Page 27, Section 2.4.3]

Natural Resources Canada

there is little consideration to the role of microbes acting on organic matter in clay sediments. The low organic content of the buffer and backfill materials does not preclude the possibility of significant biogenic gas production. Gas generation would increase the pressure in the material, most likely causing parting along planes of weakness. Parting planes would provide high velocity conduits through the backfill. [Comment 807, Source Document ph2gov001a, Page 10, Section 2.2.3]

Northumberland Environmental Protection

it has been recognised for decades that the greatest threat to buried copper occurs in the absence of oxygen under anoxic conditions, due to microbial action. Our concern is that this MIC (Microbially Influenced Corrosion) could be the MOST DAMAGING IMPACT OF ALL to a buried copper container over long timescales.... The manner in which the EIS ignores MIC is unacceptable, ... Microbial species cannot be treated as mere adjuncts of physics or chemistry. The mechanisms of fluctuating populations cannot be modeled, predicted or controlled, except in very short-term.... in practice, the AECL simply NEGLECTS TO INCLUDE the whole problem of microbes, by applying ASSUMPTIONS of EXCLUSION.... It is noteworthy, that SRB and microbes which have been chiefly implicated in microbial induced corrosion of copper, are those found chiefly in HYPERSALINE environments or brackish water. These are the anaerobic halophiles, namely the fermentatative, sulphate reducing methanogenic bacteria. Perhaps this is the single most important reason why copper container should not be buried deep in an environment such as the Canadian Shield where saline conditions prevail. [Comment 1502, Source Document cs027, Page 2]

neither AECL nor the AECB nor the SRG reviewers have even touched upon the implications of microbial alteration on future dissolution, solubility or corrosion mechanisms. The disposal concept depends absolutely on these parameters. Because of the global burgeoning of the technology and the consequent increasing possibility of future hazards of environmental impacts of contamination by newly altered and released microbial species; ... no reliance can be put upon the figures of alloy immunity to microbiologically influenced corrosion.... the effects of microbial corrosion on metal or alloy containers in a disturbed and possibly contaminated site is a future failure mechanism that could occur and can't be planned for. [Comment 1333, Source Document ph2pub010b, Page 08]

the immunity to microbially influenced corrosion we have lived with, and all the related specific properties, such as effects of aerobic conditions or sulphate concentrations, can no longer be taken as a continued assurance, in the disturbed zones of the vault and backfill. We can put no reliance on these relationships and mechanisms. The contention that microbial influences would be minimal when oxidative mechanisms ceased would not necessarily hold for altered artificial microbial forces. [Comment 1334, Source Document ph2pub010b, Page 09]

Northwatch

the EIS should be amended to include a discussion of the microbial action and its effect on corrosion [Comment 1364, Source Document pub046, Page 13, Section d]

Scientific Review Group

AECL has not demonstrated convincingly that the effect of microorganisms in the hot vault environment, under saturated or partially saturated conditions, can safely be ignored.... microbial activity may indirectly enhance radionuclide release. On the other hand, microbial activity in the buffer and backfill (supported in part by the organic materials present in the vault) may limit the transport of radionuclides through these media. [Comment 366, Source Document tec004, Page 051, Section 6.2.3]

the role of microbiological processes in groundwaters surrounding the vault should be given careful attention. AECL appears to have neglected biological processes in some of its calculations of the chemical environment at depth as they may affect the integrity of the containers, the vault, or the movement of groundwaters.... Biological activities within the vault environment should have been appraised for their possible effects on (1) corrosion of the fuel waste container; (2) clogging and gas formation within the sand annulus surrounding the depository containers; (3) gas formation or clogging in the buffer material, impeding or accelerating movement of escaped radionuclides; (4) clogging of the backfill; (5) chemical reactions and fillings in the fractures of the excavation damage zone. [Comment 394, Source Document tec004, Page 063, Section 6.4.2]

there is concern about the impact of hydrogen generated in the vault environment compromising the containers through embrittlement and corrosive processes.... No attention is paid to the potential for the microbial generation of hydrogen as a result of fermentative or chemolithotrophic functions. There is a growing body of evidence which suggests that within the geosphere there may be bacteria able to capitalize on the hydrogen - proton cycle [Comment 35, Source Document tec004, Page 121, Section B-2.1.7]

The number of potential sources of nutrients that could promote microbiologic activity and possible detrimental environmental effects directly within the vault environment may be substantial. Nutrient migration in groundwater could develop during construction or operation, promoting greater spatial distributions of presently limited biologic populations which are estimated to exist within the geosphere. This factor [microbial activity] continues to be discounted for scenario analysis. [Comment 148, Source Document tec004, Page 170, Section E-2.1.4]

Substantiation of the corrosion potential of biofilms upon titanium metal under vault conditions should have been presented ... The following additional issues related to potential microbial activities in the vault environment have not been sufficiently considered ... R-Vault states that micro-organisms and complexed radionuclides may be effectively immobilized within the buffer and backfill materials ... No justification of this assumption has been presented.... Further specification on the size distribution, porosity, and pore size of buffer and backfill aggregate should have been provided. [Comment 228, Source Document tec004, Page 207, Section F-2.2.3]

The influence and significance of microbial activity is discounted on the basis of lack of available nutrients, and of adverse environmental conditions following post-closure resaturation of the vault environment; but the document is lacking in scientific documentation and logically compelling arguments concerning these conclusions. Large uncertainties concerning the timing and conditions of the post-closure resaturation of the vault complicate the evaluation of the role of microbial intervention in the performance of the disposal system ... intense microbial activity could occur within the vault environment ... it could include the generation of methane, carbon dioxide, hydrogen or nitrogen gas, and the bioaccumulation and mobilization of contaminants within biocolloids and biofilms. The role of microbes in facilitating or inhibiting the transport of contaminants from the vault to the surface environment needs to be thoroughly investigated. [Comment 244, Source Document tec004, Page 219, Section G-3.2.5]

there is a potential, however remote, for biomobilization to occur in the vault close to or at the container walls and to rapidly transport the contaminants towards the surface. [Comment 310, Source Document tec004, Page 243, Section I-2.5]

Microorganisms have been found to be active even in extreme environments.... High vault temperatures, considered not to exceed 100 C, should support the growth of thermophilic microorganisms where other environmental factors are favourable.... radiation-resistant bacteria, if not present in the buffer material adjacent to the container, could possibly be created through processes of adaptation and mutagenesis ... hydrostatic pressures, created in the vault upon saturation, would not necessarily restrict microbial activity ... The potential for microorganisms to penetrate the very small pore sizes (e.g. less than one micron) of the buffer, and colonize the buffer also was noted [Comment 314, Source Document tec004, Page 245, Section I-2.8]

little attempt was made to address the various mechanisms by which microorganisms could compromise the container (e.g., corrosive processes, fouling, localized changes in the permeability and physical characteristics of the support media).... in the case of titanium and its alloys, there has not been a sufficient scientifically-based history of the use of various forms of titanium-based alloys to make the claim that at least some of the alloys would be resistant to microbially-induced corrosion over any extended period of time.... immunity has not been demonstrated in any long-term experiments or examples where these alloys have been exposed to conditions similar to the resaturating vault environment. [Comment 315, Source Document tec004, Page 245, Section I-2.9]

AECL has recognized that radiolysis generated through the container wall into the outside environment may set up redox fronts close to, or at, the container wall. Such fronts may tend to act as focused sites for biological activity. This issue has not been considered in sufficient detail. [Comment 318, Source Document tec004, Page 246, Section I-2.12]

A slow saturation of the vault in which water would gradually move up the vertical sides of the container creating a slowly moving redox front at the liquid - air interface is another factor which could create a focusing of microbial activity near to, or at, the container wall. [Comment 319, Source Document tec004, Page 246, Section I-2.13]

OPG RESPONSE

There is a broad international interest in microbial behaviour in the vault. In the Canadian program, the multi-year in-situ Buffer-Container Experiment and the Isothermal Test (Stroes-Gascoyne et al 2000) have had examination of microbial effects as an important part of their objectives. Recent summaries of the state-of-knowledge of microbial activities around the repository in general are given by Pedersen (2000) and Stroes-Gascoyne et al. (1997). A specific summary of the state-of-knowledge with respect to microbial induced corrosion (MIC) is given in Jain and Ogundele (2001). A detailed model of microbial processes has also been developed to help understand the key microbial processes (King et al. 2003).

General observations from this ongoing research include:

- Diverse microbial populations are known to exist in rock conditions at repository depth, but they survive at a low level of activity;

- MIC of copper has been demonstrated in the laboratory under favourable conditions;

- Microbial activity is greatly limited by low water activity levels, as well as by gamma radiation and nutrient supply;

- In dense clays, water activity can be made very small by combination of heating, salinity effects and clay density;

- A "microbiologically inactive zone" can be created near the container by suitable design and installation;

- Migration of microbes (or metabolite products) through dense clay is very slow (e.g. Stroes-Gascoyne 1999), but possible migration along cracks during resaturation has not been studied in detail.

- Substantive gas generation rates have not been seen;

- Buffer tests show that the material reseals on rewetting, suggesting that any cracking due to heating or gas breakthrough will self-seal.

In response to the results of OPG's microbial R&D program and the findings of international microbial studies, in 2002 OPG updated the Canadian design of the buffer sealing material near the container surface to 100% bentonite clay to reduce the threat of MIC (see Russell and Simmons 2003). This updated buffer design is consistent with similar repository concepts in Sweden and Finland.

Work is presently continuing in Canada and elsewhere to improve our understanding of microbial effects in the Canadian repository environment. It is expected that any future safety assessment would contain a current summary of the potential effects of microbes on the repository. The current understanding of microbial processes within the vault in any future OPG safety assessment can be found through the corresponding OPG FEPs database under FEP#2.1.10, Biological Process and Conditions (Vault).

References

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4.02.06.05 System Performance - General - Microbes - In the Geosphere PARTICIPANT COMMENTS

Scientific Review Group

potential biological content of fractures, and how this could affect contaminant transport, is not addressed. [Comment 510, Source Document tec004, Page 106, Section A-2.1.3]

The subsurface and soil microorganisms could interface with the radionuclides and significantly influence their rates of release to the surface biosphere through such activities as bioaccumulation and subsequent sloughing of parts of the biofilm. Such phenomena cannot be readily linearized as a predictable function due to the complex nature of the biological processes involved.... Biofilms are dynamic biological entities which could become unstable resulting in sloughing events. When a biofilm sloughs, some of the contents of the biofilm become suspended as particles within the surrounding water to form biocolloids. These are colloidal particles which retain some viable organisms and are biologically active. The sorption of radionuclides onto biocolloids may have very different characteristics and should be considered in the development of the disposal concept. [Comment 306, Source Document tec004, Page 242, Section I-2.3]

OPG RESPONSE

There is a broad international interest in transport in fractures, with a number of experiments underway in natural settings. In the Canadian program, the work in the MFR (Moderately Fractured Rock) experiment at the Underground Research Laboratory is one notable example. In such multi-year tests, biofilms and colloids can be active and influence the results. Some interesting results are noted below:

Biofilms:

- Vandergraaf et al (1997) scoping tests indicated that the effects of biofilms are well within the uncertainties associated with the safety assessment calculations (granite with induced biofilm, tested with Se, Sn and Cs. Minor holdup effect on Se and Cs, no effect on Sn).

- In the AECL-OPG MFR experiments, soluble species were deliberately injected and then monitored at the outflow points. It is difficult to unambiguously characterize the transport parameters for a fracture region; whether or not biofilms contributed to the delay of these species could not be seen within the uncertainties of these tests.

Colloids:

- In the AECL-OPG MFR TT2 and TT3 experiments, colloids were deliberately injected and then monitored at the outflow points. In this test, soluble contaminants were observed at the outflow points, but the colloids were not observed indicating that they were held up within the fractures.

Overall, present information indicates that the effect of biofilms and colloids are likely to be within the range of uncertainties associated with present transport property measurements, and that colloid concentrations are likely to be small enough that colloid transport is not significant. A similar conclusion was reached in the SR97 safety assessment [SKB 1999]. However, as part of any future safety assessments, we would expect to review the current understanding of such processes at that time. It is also likely that an underground test facility would be constructed at any candidate site, and tracer tests in fractures at site conditions would likely be carried out.

References

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4.02.06.06 System Performance - General - Microbes - In the Biosphere PARTICIPANT COMMENTS

Scientific Review Group

R-Biosphere ... ignores the probability that the radionuclides may also travel in groundwater bound onto biocolloidal or colloidal particles which may, or may not, incorporate biological entities.... It is probable that the biological components of the sediment would play critical, if not dominant, roles in the movement of radionuclides through the sediments. Where the radionuclides are assumed to be integrated into biocolloidal entities within the sediment, there is a potential of accelerated as well as retarded movement. [Comment 307, Source Document tec004, Page 243, Section I-2.4]

at a water well, positioned within the contaminated groundwater plume, ... discharge would automatically be compromised in both a positive (biozone accumulation) and a negative (accumulate sloughing from a collapsing biozone) event from in and around a well. The possibility of a sudden entry of radionuclides into the surface biosphere as a result of the combination of the above events has not been discussed in sufficient detail. [Comment 309, Source Document tec004, Page 243, Section I-2.5]

OPG RESPONSE

Recent results are certainly consistent with the SRG view that colloids can be important in soils and sediments in the surface biosphere, as distinct from the overburden, where colloid levels may be low and not important (eg. Vilks et al 1998 for the sandy aquifer at Chalk River, Ontario).

For example, the SKB SR97 safety assessment found that bioturbation was important in moving contaminants through the soil [Lindgren and Lindstrom 1999, Bergstrom et al. 1999]. Canadian models that ignored these processes overestimated doses for nuclide that sorbed strongly on soils by as much as a factor of 100 in comparison with SKB models [Garisto et al. 2001]. Also, the IAEA 2001 assessment of the Yucca Mountain Project's biosphere model also noted that "...migration of radionuclides in the soil is dominated by the migration of radionuclides that are bound to very small particles...especially for radionuclides that are strongly bound to soil." [IAEA 2001].

However:

1. The I-129 and CI-36 nuclides that tend to dominate the dose in Canadian postclosure safety assessment studies are not strongly affected by these processes.

2. The transport/holdup through the sediments/soil layer is typically short compared to the transport/holdup through the vault and geosphere materials, so uncertainties in the soil model have less effect on the contaminant release to the surface.

3. Nuclide holdup on soils is typically modelled by Kd's, which are measured experimentally under systems that would often have natural levels of colloid present, and so include their contribution to the overall soil/water balance.

With respect to the possibility of periodic accumulation and sloughing of biofilms at wells, it is noted that the dose estimates of interest are over long time scales, which would tend to average out short term decreases or spikes in dose rates.

In general, the possibility of microbial effects on transport and sorption in the biosphere needs to be considered as part of any future safety assessment, taking into account current understanding of colloids and of site-specific data. This assessment can be tracked via the FEPs Database for that particular safety assessment (e.g. see the Third Case Study FEPs report, #3.2.04, 3.2.05 and 3.2.06, Garisto et al. in prep.).

References

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M. Lindgren and F. Lindstrom. 1999. SR97 Radionuclide transport calculations. SKB report TR-99-23. Stockholm, Sweden.

P. Vilks, F. Caron and M. Haas. 1998. Potential for the formation and migration of colloidal material from a near-surface waste disposal site. Applied Geochem., Vol.13, pp.31-42.
4.02.07 System Performance - General - Radon Gas Production PARTICIPANT COMMENTS

Scientific Review Group

Production of radon gas from buffer, backfill and rock surrounding the underground workings, or from waste rock on surface has not been adequately assessed.... Exposure of workers to radon and radon progeny can result not only from naturally occurring radioactive materials in Canadian Shield plutonic rocks, but also from buffer and backfill materials.... an order of magnitude calculation, and case studies, to verify that minimal health hazard exists should have been presented. [Comment 79, Source Document tec004, Page 136, Section C-2.1.5]

OPG RESPONSE

Preliminary occupational safety analyses were conducted for the 1994 EIS submitted by AECL, and found to be acceptable (Preclosure report, p.5-1). More detailed occupational safety analyses would be conducted when design and site-specific data are available.

Radon gas and its decay products are routinely encountered in underground mines. The repository is expected to be licensed by regulatory authorities which will require occupational doses to be acceptable. The normal process to deal with underground radon is to ensure that the ventilation is adequate to ensure that occupational doses are below target.

Reference:

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4.02.08 System Performance - General - Colloids

PARTICIPANT COMMENTS

Atomic Energy Control Board

AECL has not adequately considered the potential impacts of colloids on radionuclide transport.... it is assumed by AECL that the mass of rock available for sorption depends on the porosity of the rock and that rock can be represented as an equivalent porous medium. However, ... the assumption of an equivalent porous medium [may be] invalid if applied to low porosity fractured rock, particularly if radiocolloid formation is irreversible.... it is assumed that any radiocolloids formed inside the container would be filtered out by the buffer. However, there are no experimental data presented to support this assumption. Because the colloid size-range includes particles that are of the same size as dissolved ions (i.e., < 450 nm) there is no obvious reason why colloids could not diffuse through the buffer as effectively as ions. [Comment 641, Source Document gov002, Page 58, Section C.3.2(ii)]

Scientific Review Group

Colloids would be introduced with crushed granite in the backfill. [Comment 151, Source Document tec004, Page 170, Section E-2.1.4]

OPG RESPONSE

It is noted that dissolved ions (of CI, U, I etc.) have a size of the order of 0.2 nm, whereas colloids are considered to be in the size range of around 1-450 nm.

A good summary of the understanding of colloids at the time of the EIS is Vilks (1994). Since the EIS, there has been further work on colloids and their possible influence on radionuclide transport. A brief summary of some of this work is highlighted below.

Within the buffer:

Colloids might be formed from organics or from clay particles. Clay colloids would be expected to interact with the buffer material, and not move quickly. Clay colloids might be released at the buffer/geosphere interface, but in this case they will still likely interact with common fracture minerals and therefore not travel far (Pusch 2001 p.128).

Organics colloids might be negatively charged, and therefore have less interaction with the clay background materials. Within the Canadian clay-based buffer, measurements have indicated amounts of organics in porewater on the order of 10 mg/L (Stroes-Gascoyne 2000), an amount that SKB (SR97) considered a threshold for whether organic colloids could influence transport (Andersson 1999, p.49).

Furthermore, due to the small size of the pores in dense buffer, the transport of colloids is expected to be inhibited (e.g.. Cigar Lake analog data, Cramer and Smellie 1994, p.240; Pusch 2001, p.142).

Within the geosphere:

Data from deep rock groundwaters at Whiteshell and Atikokan indicate low total colloid levels (Vilks and Bachinski 1997, Vilks et al 1998). SKB also reports low organic compounds in their sites (Andersson 1999, p.49). Natural analog evidence from Cigar Lake indicates little mobilization of the clay into the rock (Cramer and Smellie 1994), and evidence from Maqarin indicates that the amount of colloidal material generated by cements in the vault will probably be low (Smellie 1998). If sorption on colloids is reversible, then these levels are not expected to lead to any significant nuclide transport (Vilks and Bachinski 1997, Andersson 1999). However, it appears that U, Th and Ra may be irreversibly sorbed (Cramer and Smellie 1994), so - if these colloids reach the geosphere - transport may be important.. MFR experiments at the URL in which colloids were deliberately introduced into

fractures showed no breakthrough at the observation points, even though the other tracers reached the observation point on the expected time scales, indicating that colloid transport through moderately fractured rock acted more as a filter than as a conduit for colloids (Vandergraaf 2000).

Experimental work on colloid transport in buffer and in geosphere is continuing, and the current understanding would be reflected in the data and models used for any future safety assessment. The status of colloids in the context of any specific OPG safety assessment can be found in the corresponding FEPs Database entry #3.2.04 Colloid Interactions and Transport.

References

Andersson J.. 1999. SR97 Data and data uncertainties. SKB TR-99-09.

Cramer J. and J.A.T. Smellie (eds.). 1994. Final report of the AECL/SKB Cigar Lake Analog Study. SKB Technical Report 94-04.

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Stroes-Gascoyne S., C. Hamon and P. Vilks. 2000. Microbial analysis of the Isothermal Test at AECL's Underground Research Laboratory. OPG 06819-REP-01200-10023 R0.

Vandergraaf, T.T. et al. 2001. Moderately fractured rock experiment Stage 2 report: Large and medium-scale migration experiments. OPG report 06819-REP-01300-10028-R00..

Vilks P. 1994. The role of colloids and suspended particles in radionuclide transport in the Canadian concept for nuclear fuel waste disposal. AECL-10280, COG-92-26.

Vilks P. and D. Bachinski. 1997. Natural colloids in groundwater from granite and their potential impact on radionuclide transport. AECL-11635, COG-96-311-I.

Vilks P., F. Caron and M. Haas. 1998. Potential for the formation and migration of colloidal material from a near-surface waste disposal site. Applied Geochem., 13, pp.31-42 (AECL-11935).

4.02.09 System Performance - General - Glaciation

PARTICIPANT COMMENTS

Canadian Geoscience Council

New data about glaciations becoming available through ice-cores and new ideas about the extremely rapid onset of glaciations (the so-called Heimlich cycles) should be watched and examined closely during the coming year. [Comment 1050, Source Document tec002, Page 18, Section 3.3.2]

Chemical Institute of Canada

it would seem that the effects of an ice age ... could induce tremendous forces on the storage area - ... from the surface due to ice ... such events further raise the question of premature failure of containers and subsequent leakage. [Comment 1128, Source Document tec005, Page 23, Section IV.i.3]

Durham Wetlands and Watersheds

Discussion of Continental Glaciation in the EIS is inadequate.... research [should] be done regarding the last Continental Glaciation to measure exactly what erosion took place and research the same if possible for the three preceding Continental Glaciations.... crustal rebound [should] be researched more fully by measuring the rebound now occurring at Hudson and James Bays with that occurring adjacent the Great Lakes particularly Lakes Erie and Ontario.... meteorological research already done ... [should] be used to more accurately predict when a future glaciation may or may not occur.... remote sensing and satellite imagery [should] be used in the EIS to precisely delineate where Continental Glaciations will originate and predict where erosion and crustal depression will occur. [Comment 1998, Source Document pub043, Page 2]

Northwatch (Richardson)

given the importance placed by AECL on the low-angle fracture zone LD1, it is perhaps unfortunate that the EIS itself contains no discussion of the potential effects on such fractures from glaciation, merely referring the reader to R-Geosphere.... To blandly dismiss the potential effects of glaciation in a northern latitude country such as Canada, is not satisfactory. [Comment 1523, Source Document ph2pub009, Page 15, Section 3]

OECD/NEA Review Group

The main driving forces which might lead to 'sudden and dramatic increases' in release (if not dose) beyond 10,000 years are permafrost and/or glaciation caused by a climate change and the physical processes associated with glaciation, so some sort of quantitative consideration of the processes involved does seem to be required. [Comment 1221, Source Document tec001, Page 12, Section 4.1]

Scientific Review Group

The possibility of ... glacial loading have been understated in the EBS design and assumed performance... glacial loading, could induce stress variations over periods of millennia.... The effects of ... glacial loading may be non-trivial for the reference design, in which the state of stress would lead to fracturing of the rock web between boreholes, thereby bypassing the backfill as a barrier. An invault container emplacement design would be less sensitive to disturbance by ... glacial affects. [Comment 41, Source Document tec004, Page 123, Section B-2.1.14]

AECL has discounted the potential negative effects on the vault facility that may develop due to glaciation within a time period between 10,000 and 100,000 years when such a climatic occurrence is likely to occur. Projections of glacial stress induction on eventual vault and geosphere stability also should have been considered. [Comment 153, Source Document tec004, Page 170, Section E-2.1.4]

OPG RESPONSE

The effect of glacial and peri-glacial conditions should be considered in geosphere performance assessment. In addition to qualitative arguments put forth in the EIS, the Deep Geologic Repository Technology Program (DGRTP) has initiated several projects intent on re-examining the influence of long-term climate change and glacial cycles on engineered barrier systems and geosphere performance. These efforts include a re-assessment of performance assessment modelling techniques and strategies necessary to predict flow system dynamics and geochemical stability under variable boundary conditions.

A key element in this process is the definition of the Design Basis Glacial Scenario (DBGS) (Peltier, 2001). One goal of the DBGS is to document the current scientific understanding of long-term climate change as related to glacial cycles and ice-sheet history during the Pleistocene (0-2 mya). This information will provide a basis with which to rationalize changes in boundary conditions (i.e. hydraulic; mechanical; chemical) during the periods of time and space relevant to demonstrating repository safety. Current DGRTP work program activities involve improved predictions of Laurenitide ice-sheet migration which are better constrained by recently obtained multi-disciplinary geodetic and glacial geomorphological data. An intent of the DGRTP is to couple such predictions with models of type Shield regional and local groundwater flow systems to; i) demonstrate issues of groundwater flow system evolution and stability relevant to site characterisation and repository safety; and ii) to provide further evidence related to the robustness of numerical predictions in flow system evolution.

Field related research to explore the influence of long-term climate change includes the international PERMAFROST project (Ruskeeniemi et. Al. 2002). This project, undertaken jointly with Posiva (Finland), the Geological Survey of Finland (GTK), SKB (Sweden), and Nirex (United Kingdom), strives to increase the understanding of permafrost on fractured crystalline flow system evolution. In parallel with these field studies, a series of numerical thermodynamic and laboratory freezing experiments have been conducted with type Canadian and Fennoscandian Shield groundwaters (Zhang and Frape, 2002). The purpose of these experiments is to provide evidence of groundwater chemical and isotopic evolution as a reasoned basis and additional constraint on the identification of permafrost or 'freeze-out' signatures in groundwaters. Examples are provides in Zhang and Frape (2002) how this information aids in understanding flow system dynamics in crystalline settings during glaciation. Other work program activities include the DECOVALEX III program which is assessing numerically coupled hydraulic-mechanical geosphere (i.e. stress, groundwater flow) responses to glacial cycles (Chan and Stanchell, 2003) and a paleohydrogeologic study examining the petrogenesis of fracture infill minerals within the Whiteshell Research Area (McMurry and Ejeckam, 2002). This latter study provides evidence to quantitatively assess the depth of penetration by low-salinity, oxygenated glacial recharge that could affect radionuclide mobility and engineered barrier system performance.

References

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Ruskeeniemi, T., M. Paananen, L. Ahonen, J. Kaija, A. Kuivamaki, S, Frape, L. Moren and P. Degnan, 2002, PERMAFROST at Lupin Report of Phase, Geologic Survey of Finland Report YST-112.

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Chan, T. and F.W. Stanchell, 2003, DECOVALEX III, BMT3 Glaciation Bench Mark Test, Phase I, Progress Report, Ontario Power Generation Report No. 06819-REP--1300-10060-R00.

McMurry, J and R. Ejeckam, 2002, Paleohydrogeological Study of Fracture Mineralogy in the Whiteshell Research Area, Ontario Power Generation Report No. 06819-REP-01200-10082-R00.

4.02.10 System Performance - General - Seismic Events PARTICIPANT COMMENTS

Atomic Energy Control Board

AECL does not sufficiently justify the elimination of seismicity and tectonics from consideration in the postclosure safety assessment. AECL is placing too much emphasis on the documented earthquake record which, in Canada, is far too short to provide a reliable indication that major earthquakes would not be expected in any areas studied to date.... There are too many unsupported statements suggesting that the Canadian Shield has not been subjected to any major tectonism in the last 600 million years, therefore implying that no site located in the Shield will experience damaging earthquakes.... Sanford's work and other recent studies indicate that orogenic activity occurred in Southern Ontario in the last 500 million years [Comment 656, Source Document gov002, Page 65, Section C.6.3]

Campaign for Nuclear Phaseout

The real possibility, although small, of an earthquake happening at the site of a repository was not treated very seriously by the proponent: what would happen if a large magnitude earthquake did hit a nuclear fuel waste repository? What measures would be taken to insure the safety of Canadians in such a case? [Comment 1828, Source Document phpub104, Page 02]

Vaults that would be constructed in the implementation of the concept would create human engineered fracture zones, an issue which the EIS does not address in its consideration of ground faults and earthquakes. [Comment 1803, Source Document pub027, Page 26, Section III.E]

Current geological knowledge precludes prediction of earthquakes with any degree of certainty.... In its consideration of geological stability and seismic monitoring the EIS considers only the implications of active ground faults. In this respect, it fall short of the criteria outlined in Section 7.11 of the Final Guidelines which state that an analysis of data limitations due to the choice of measurement technique and data interpretation should be provided. It also fails to discuss the consequences of such limitations, as is prescribed in Section 7.11. The descriptions of methods used to identify and characterize fracture systems and major fracture zones is not accompanied by a critical analysis of the methodology. [Comment 1813, Source Document pub027, Page 30, Section III.G]

Canadian Coalition for Nuclear Responsibility (Regroupement pour la surveillance du nucléaire)

The Ungava earthquake ... was totally unexpected and unpredictable. One should not overlook the Saguenay 1988 earthquake in this context either. It should be borne in mind that earthquakes are not truly random events, and therefore probabilistic arguments are highly suspect. [Comment 1896, Source Document pub049, Page 41]

In the event of a nearby earthquake, is it not conceivable that the weakening of the rock caused by excavation of the repository might make earthquake damage more extensive than it might otherwise have been? [Comment 1897, Source Document pub049, Page 41]

Catholic Women's League of Canada

One of our main concerns is that of earthquakes. ... There cannot be any guarantee of no earth movement for the necessary thousands of years required for the concept in question. [Comment 1922, Source Document ph3pub009, Page 2]

Catholic Women's League of Canada - Ontario

Our concerns about the concept include the possibility of earthquakes resulting from faults that could not have been recognized as such prior to the quake and which could be extremely hazardous if located in an area where nuclear waste has been buried. [Comment 1929, Source Document ph3pub209, Page 2]

Chemical Institute of Canada

it would seem that the effects of an ... earthquake could induce tremendous forces on the storage area - ... within the ground from earthquake shock waves.... such events further raise the question of premature failure of containers and subsequent leakage. [Comment 1265, Source Document tec005, Page 23, Section IV.i.3]

National Council of Women of Canada

On March 14, 1996, there was an earthquake which measured 4.5 on the Richter scale centred in the Laurentian (part of the Canadian Shield) and felt in Ottawa and Quebec City. While the Shield is known to be one of the most stable land masses, no one can know whether this remarkable property will last for the thousands of years required for safe burial. This should be admitted as a matter of ethical consideration. [Comment 1496, Source Document ph3pub185, Page 4]

Natural Resources Canada

The Niagara Peninsula should be added to the list of places where rather more of the Ontario earthquakes have occurred in historic time. [Comment 782, Source Document ph2gov001, Page pos5]

The statement "...earthquakes tend to occur in zones that have exhibited seismic activity in the past ..."2, is true only as a generality and is an insufficient basis on which to site and design a repository.... we cannot use just the absence of microseismicity to claim the threat of large earthquakes is "negligible". [Comment 783, Source Document ph2gov001, Page pos5]

On p. 641 the authors list events that could damage the disposal system and its contents. Regional strain changes should be added to this list. [Comment 784, Source Document ph2gov001, Page pos6]

The authors imply that only splays and secondary fractures that widen the fault zone are significant. It is suggested instead that it is the lengthening, by propagation of a dead-end fracture into unfractured rock, which is important. Candidates for lengthening would be fractures distant from the vault site that die out entirely, but if extended during an earthquake rupture (presumably started on an existing fault and propagating onto the dead-end fracture because of favourable geometry) might intersect the vault.... the chances of this happening will depend on the number of suitably oriented dead-end fractures aimed at the vault and the chances that the fault/fracture will be re-activated. [Comment 785, Source Document ph2gov001, Page pos6]

It is not clear whether the authors (Davison et al. (1994a)) are saying that there is "no evidence for repeated movement" or that "evidence is that recurrent movement has not taken place". [Comment 786, Source Document ph2gov001, Page pos6]

We disagree with the argument that fault reactivation takes place chiefly during continental collisions. [Comment 787, Source Document ph2gov001, Page pos6]

The proviso that safety will be assured if certain distances from active faults are excluded is sensible, but its premise is dubious: a) how will the past activity of the fault be assessed b) how will the potential for future activity of the fault be assessed c) will it really be possible to find and identify all faults that have had recent ruptures d) can we really identify all those other faults that might rupture in the future e) are we sure that 1 or 2 km below the underground research laboratory (URL) an active fault does not exist. We are not convinced that the current state of the art is sufficient to avoid the site of the next M6 or greater earthquake in northern Ontario. It is incorrect to suggest that methods exist or can soon be developed, to identify all important active faults, at least in concept. [Comment 788, Source Document ph2gov001, Page pos7]

While screening with the present information may help, the information known now, or that will be understood through research over the next 25 years, will not allow a rigourous screening to address the concerns about earthquakes. [Comment 790, Source Document ph2gov001, Page pos8]

Seismicity is not just a screening issue, in that even if a site passes a screening test, earthquake issues still need to be addressed during the construction, operation and postclosure phases. [Comment 791, Source Document ph2gov001, Page pos8]

earthquakes of magnitude 4 or larger have also been induced by removal of load, by quarrying or by hydrocarbon extraction. Removal of mass will tend to destabilize thrust faults under the vault, a type of faulting that is expected for the Canadian Shield.... an estimate of the mass removed and some assessment of worldwide case studies of earthquakes induced by unloading should be made to assess the hazard. [Comment 796, Source Document ph2gov001a, Page 07, Section 2.2.1]

AECL needs to demonstrate that the effects of significant earthquakes (and glacial rebound) would not cause dangerous levels of failure within the rocks surrounding the entombed nuclear fuel because of the weakened layer. [Comment 797, Source Document ph2gov001a, Page 07, Section 2.2.1]

the approach to siting a vault far from regions of clustering current earthquake activity, major rifts and major regional fault zones may not be sufficient to ensure the integrity of the vault and its surrounding plutonic rock for the next 10,000 years.... Lacking evidence to the contrary, we believe that earthquakes like the Ungava earthquake event can occur in almost any part of the Shield, though perhaps very infrequently in any given region.... the potential for an earthquake occurring in the next 10,000 years should not be considered negligible and ignored, but should be considered as part of a risk-reduction strategy influencing the entire preclosure phase.... we are not convinced that the current state of the art is sufficient to avoid the site of the next magnitude 6 or greater earthquake in the Canadian Shield.... We strongly recommend that seismicity not be considered solely a screening issue, but rather, an ongoing issue to be addressed during the construction, operation and postclosure phases. We suggest that the correct approach for seismicity is to perform a hazard analysis for the long-lifespan repository, and then adopt a design level consistent with that hazard analysis and the required safety level during construction and operations phases. [Comment 810, Source Document ph2gov001a, Page 11, Section 2.3.1]

The understanding of hydrogeological effects from earthquakes is incomplete, but large earthquakes cause hydrological changes tens of kilometres away from the fault.... Those effects have not been discussed by AECL [Comment 811, Source Document ph2gov001a, Page 12, Section 2.3.1]

Northwatch (Richardson)

The other factor worthy of comment is glacially induced seismicity. As with glaciation, this is rather blandly dismissed in the EIS (p312) by reference again to R-Geosphere.... the major risk from glacially induced seismicity would not necessarily appear to come from repository damage, (dismissed in the EIS), but from induced changes in hydrology. [Comment 1524, Source Document ph2pub009, Page 16, Section 3]

Scientific Review Group

There is inadequate treatment of the question of how the potential impact of seismic activity on the permeability of low permeability rocks, which is acknowledged to pose a potential hazard to components of the engineered barrier, will be evaluated. [Comment 24, Source Document tec004, Page 113, Section A-2.2.3]

The possibility of seismic events ... have been understated in the EBS design and assumed performance Seismic activity ... could induce stress variations over periods of millennia.... The effects of seismic activity ... may be non-trivial for the reference design, in which the state of stress would lead to fracturing of the rock web between boreholes, thereby bypassing the backfill as a barrier. An in-vault container emplacement design would be less sensitive to disturbance by seismic ... affects. [Comment 493, Source Document tec004, Page 123, Section B-2.1.14]

OPG RESPONSE

In the EIS, one of the technical factors to be considered for site screening was rock mass stability and low seismicity/seismic risk. This factor would be addressed by considering siting regions and subsequent candidate areas where there was no evidence of post-glacial faulting, were within seismic hazard zones 0 or 1, and were removed from current seismic activity, seismically-active faults, major structural zone contacts or major fault zones. Clearly, the intent is to minimize the probability of significant future seismic events from impacting on the construction, operation and post-closure phases of repository history. However, it is unlikely that the probability of seismic events occurring near a repository can be reduced to zero. Consequently, improving confidence in the effect of seismic activity on repository performance through improved knowledge and understanding of factors that have governed geosphere stability (i.e. hydrogeochemical evolution/origin of matrix/fracture fluids, fracture rejuvenation/propagation, hydrogeologic/geomechanical response to glaciation and paleohydrogeology) at time frames necessary to demonstrate safety remains a key aspect of the Deep Geologic Repository Technology Program (DGRTP).

In 2001, the DGRTP began working with the University of Toronto to develop a Design Basis Glacier Scenario (DBGS) in support of an updated Safety Case for a deep geologic repository on the Ontario portion of the Canadian Shield (Peltier, 2001). This conceptual model provides insight into Laurentide glacial ice sheet history relevant to understanding neotectonics and the potential for glacially induced fracture rejuvenation or reactivation in a Shield setting. This work is further being advanced through the DECOVALEX III program in which coupled 3-dimensional hydraulic-mechanical numerical simulations of geosphere geomechanical and hydrogeologic evolution during an approximately 110ka glacial cycle are being explored (Chan and Stanchell, 2003).

The DGRTP has monitored progress of the Geological Survey of Canada's LITHOPROBE activities within the Canadian Shield's Superior Province. LITHOPROBE is Canada's national earth science research project to investigate the 3-dimensional structure and evolution of Canada's landmass and continental margins. One of the benefits of the program will be the provision of a regional geotectonic context within which petroleum and mining companies can better plan their programs. A siting process, initiated by a future waste management organization, will benefit from the fundamental knowledge gained of crustal processes and Shield history.

In collaboration with the Geological Survey of Canada, the DGRTP is supporting a study in which Apatite Fission Track Thermochronology (AFT) is applied to investigate regional basement reactivation and fracture propagation (Everitt and Osadetz, 2000; Everitt et. al., 2002). The study indicates a protracted history of Phanerozoic burial, uplift and erosion for the Lac du Bonnet batholith. It is reasoned that if fracture propagation were an on-going process within the batholith, traces should have been evident from periods of active tectonism. However, relatively simple fracture geometries and preservation of large domains of sparsely fractured rock within the Lac du Bonnet batholith suggest that post-Archean (2.4 Ga) fracture propagation has been minor. In 2001, the DGRTP is working with the University of Waterloo to conduct illustrative 3-dimensional numerical analyses of regional and repository scale groundwater flow in a fractured crystalline setting characteristic of the Canadian Shield (Sykes et. al., 2002). The numerical analysis will demonstrate the effect of topographic and density gradients, flow system permeability distributions and transient boundary conditions associated with glaciation on predicted groundwater flow paths and residence times. Interim results from this work program provide a reasoned basis to indicate that density gradients resulting from increased salinity with depth may play a significant role in governing groundwater flow paths and residence times at geologically significant time periods (i.e. existence of stagnant or sluggish groundwater flow system at the repository horizon). Such illustrative examples coupled with on-going Paleohydrogeologic studies (i.e. Whiteshell Research Area fracture infill mineralogy - McMurry and Ejeckham, 2002) that provide evidence of long-term hydrogeochemical stability by proxy imply that seismic activity at repository horizons (500 to 1000 m) did not significantly influence flow system evolution.

As stated in the EIS, the organization responsible for implementing the potential deep geologic repository option for nuclear waste management, may incorporate seismic design methods for surface and subsurface structures associated with the construction and operation of a repository. Based on a seismic evaluation of the underground facilities at the USDOE WIPP site (Wu, Chen and Wise, 1982), both the horizontal and vertical peak accelerations associated with earthquake events attenuate with depth in the stratigraphic column. This was consistent with the general observation that the intensity of shaking below ground was less severe than on the ground surface and the resulting damages to underground facilities reduced with depth.

In cooperation with the Geologic Survey of Canada, the DGRTP continues to support the maintenance of a network of seven seismograph stations located within the north-western Ontario portion of the Canadian Shield. This network allows the rate of natural earthquake activity to be discriminated from seismic events associated with mining. Future opportunities to improve the current ability to measure earthquake ground motion in the evaluation and mitigation of seismic activity, such as collaboration with the POLARIS research program, will be pursed if beneficial to the DGRTP.

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4.02.11 System Performance - General - Contaminants from Explosives PARTICIPANT COMMENTS

Scientific Review Group

Possible consequences of blasting have not been taken into account... The carbon and nitrates could act as a source of nutrients for microbes, and the nitrates, which are oxidizing species, may induce crevice corrosion of the container (R-Barriers, Section 2.1.7). [Comment 40, Source Document tec004, Page 122, Section B-2.1.13]

The rationale regarding residues from explosives neglects the impacts of nitrates from the explosives within the vault (not just in the surface environment). The rationale repeats the well-used assertion from R-Preclosure that impacts in the surface environment would be limited because "... discharges would be closely monitored to ensure compliance with all environmental regulations" (R-Postclosure 1994: p.206). The R-Preclosure does not provide details regarding monitoring or compliance and no details are given in R-Postclosure. This is insufficient. [Comment 190, Source Document tec004, Page 188, Section E-3.2]

OPG RESPONSE

AECL has conducted studies to assess the potential for repository construction activities to introduce microbial nutrients into the repository environment (see for example Stroes-Gascoyne and M. Gascoyne. 1998. The Introduction of Microbial Nutrients into a Nuclear Waste Disposal Vault During Excavation and Operation. Atomic Energy of Canada Limited Report AECL-11926).

OPG has conducted studies examining the potential impact of microbial activity in a deep geologic repository with nutrients introduced by the construction process (see Ager and Jain 2000, Microbial gas production in mixtures of reference buffer material and standard Canadian Shield Saline Solution, OPG Report 06819-REP-01200-10021-R00). The impacts are expected to be very small.

4.02.12 System Performance - General - Sorption

PARTICIPANT COMMENTS

Environment Canada

Other issues identified as being of concern were: ... the lack of a rigorous approach to the selection of radionuclide sorption coefficients (which may not produce conservative values) [Comment 874, Source Document gov003, Page 27, Section 2.13]

Northwatch (Richardson)

There is a continuing debate over the retardation potential of different lithological mineralogies as regards migrating radionuclides. Much of the work done to date on important properties such as sorption and diffusion has been based on a series of hitherto unsubstantiated assumptions, due to inconsistencies in data and experimentation. [Comment 1557, Source Document ph3pub088, Page 09, Section 4]

Scientific Review Group

Minerals in the buffer, backfill ... will react strongly with many of the radionuclides: This assumption is, in turn dependent upon the assumption that the seal materials will be homogeneous and will have uniformly low hydraulic conductivity. This will not necessarily be the case. [Comment 142, Source Document tec004, Page 165, Section E-2.1.2]

Minerals in the ... rock will react strongly with many of the radionuclides ... there is no experimental evidence to indicate that the bulk sorptive capacity of sparsely-fractured rock is substantial. [Comment 516, Source Document tec004, Page 165, Section E-2.1.2]

OPG RESPONSE

Sorption of radionuclides on transport through clays and rocks is a well-established process.

A systematic, semi-empirical approach was used to select the radionuclide sorption coefficients. Experimental data, when available, was used first. Data from crushed rock tests were translated into values for sparsely fracture rock following a systematic approach. Otherwise, sorption values were estimated based on mineralogical similarity, conservative estimates based on mineralogy, chemical homologs, conservative estimates based on chemistry, etc. The basis of the geosphere sorption coefficients used in the EIS and SCS are documented in Vandergraaf and Ticknor (1994) and Ticknor and Vandergraaf (1996). The basis for the buffer sorption coefficients are largely documented in Johnson et al. (1996) and Oscarson et al. (1995).

If the rock is relatively homogeneous, the EIS sorption estimates for sparsely fractured rock, derived from crushed rock data following Vandergraaf and Ticknor (1994), are believed to be generally reasonable, although the sorption coefficient of Tc on granite, under reducing conditions, used in the EIS was overly conservative (see below). It is true that there is little experimental data on the bulk sorptive capacity of such rock. But there is certainly some data, such as from the Canadian In-Situ Diffusion experiments (Vilks and Miller 2002), and there are no indications that the present model is substantively wrong.

It is intended that the reference sorption models and values should be systematically reviewed, taking into account data gathered since the EIS. Recently, for example, a review of the properties of Tc (Garisto and Gierszewski 2002) indicated that the sorption coefficient for Tc on granite, under reducing conditions, is much larger than the value used in the EIS. Additional changes to the Canadian sorption database are described in Garisto (2002).

If the rock contains large-aperture fractures, then transport would likely be channelled through these

fractures and it would be appropriate to explicitly recognize this in the sorption/transport models. The use of geosphere models capable of such treatment (e.g. dual porosity) is presently being incorporated into the safety assessment methodology (Gierszewski et al. 2003). Data from transport through in individual fractures and fracture zones in crystalline rock have been carried out, such as in-situ experiments on a 50-m scale in Canada (Vandergraaf et al. 2002), a 5-m scale in Sweden (SKB 2001), and laboratory experiments on 1-m scale blocks of rock (Gierszewski et al. 2003a).

The effects of inhomogeneities (and uncertainties) in the sealing material and geosphere were approximately accounted for in the EIS and SCS since a distribution of values were used for each sorption coefficient. Further, as long as the hydraulic conductivity is less than about 1E-10 m/s for part of the path in the buffer/backfill, then transport will be largely by diffusion and the inhomogeneities are likely not to be significant with respect to transport.

The treatment of sorption in the context of any specific OPG safety assessment can be found in the corresponding FEPs Database entry #3.2.03 Sorption and Desorption (Contaminant). (e.g. Garisto et al. in prep.).

References

Garisto, F. Radionuclide and element specific data for the radionuclide screening model Version 1.1. OPG Report 06819-REP-01200-10038-R01.

Garisto, F. and P. Gierszewski. 2002. Technetium-99: Review of properties relevant to a Canadian geologic repository. OPG Report 06819-REP-01200-10081-R00

Garisto, F. et al. In preparation. Third Case Study - Features, Events and Processes. Ontario Power Generation Report 06819-REP-01200-10125-R00.

Gierszewski, P. et al. 2003a. Deep geologic repository technology program - Annual report 2002. OPG Report 06819-REP-01200-10100-R00.

Johnson, L.H., D.M. LeNeveu, F. King, D.W. Shoesmith, M. Kolar, D.W. Oscarson, S. Sunder, C. Onofrei, and J.L. Crosthwaite. 1996. The disposal of Canada's nuclear fuel waste: A study of postclosure safety of in-room emplacement of used CANDU fuel in copper containers in permeable plutonic rock; Volume 2: Vault model. AECL Report AECL-11494-2.

Oscarson, D.W., N.G. Sawatsky, W.-J. Cho and J.-W. Choi. 1995. Compacted Clays as Barriers to Radionuclide Transport. In Fifth International Conference on Radioactive Waste Management and Environmental Remediation, Berlin, Germany. Sponsored by the American Society of Mechanical Engineers, pp. 751-754.

SKB. 2001. First TRUE stage - transport of solutes in an interpreted single fracture. SKB Technical Report TR-01-24.

Ticknor, K.V. and T.T. Vandergraaf. 1996. A Revised Compilation of Sorption Coefficients for Use in Geosphere Models in Performance Assessments of Used Fuel Disposal in Granitic Environments. Atomic Energy of Canada Limited Report AECL-11343.

Vandergraaf, T.T. and K.V. Ticknor. 1994. A Compilation and Evaluation of Sorption Coefficients Used in the Geosphere Model of SYVAC for the 1990 Assessment of the Whiteshell Research Area. Atomic Energy of Canada Limited Report AECL-10546.

Vandergraaf, T. et al. 2002. Moderately Fractured Rock experimental program: annual report for FY2001/2002. OPG report 06819-REP-01300-10056-R00.

Vilks, P. and N.H. Miller. 2002. Phase II In-situ Diffusion Experiment - Annual progress report for 2001. OPG Report 06819-REP-01300-10041-R00.

4.02.13 System Performance - General - Change in Discharge Location PARTICIPANT COMMENTS

Scientific Review Group

scenarios of possible long-term changes in the linkage of surface hydrological and subsurface hydrological systems should be considered when selecting candidate sites for a disposal vault and when modelling flow paths for escaping radionuclides, especially if these affect the definition of most conservative scenarios and of critical groups of humans and non-human biota. [Comment 332, Source Document tec004, Page 039, Section 5.6]

OPG RESPONSE

The role of geosphere performance assessment, supported by site characterisation, is to provide a reasoned basis to understand groundwater flow paths at time and space scales relevant to demonstrating repository safety. There are several key issues that must be addressed to achieve this including a description of temporal and spatial variability of flow system properties and boundary conditions that could influence radionuclide migration (i.e. see 4.02.09). Ideally, a repository location would be selected within the flow domain such that anticipated long-term changes in the groundwater flow field and/or generation of new transmissive pathways would not significantly alter predicted repository performance. Justification for such siting practices would be supported by multiple-lines-of-reasoning. This would, among other factors, consider combined evidence from paleohydrogeology, environmental isotopes, hydrogeochemistry, the spatial distribution of physical flow system properties, tectonic evolution and 'what if' numerical performance assessment analyses to illustrate site robustness.

At present the Deep Geologic Repository Technology Program (DGRTP) is re-evaluating performance assessment strategies for prediction of groundwater flow and mass transport in fractured plutonic settings. This includes the planned application of the 3-dimensional codes Integrated Hydrologic Model (InHM) and FRAC3DVS (HYDROSPHERE) within the Regional Flow System Study, which is investigating groundwater flow path evolution and residence times in a type 3-dimensional Shield setting (Sykes et al., 2002). The modelling approach adopted in this study will not only improve upon the ability to evaluate predicted uncertainty in flow system evolution/patterns (e.g., discharge locations) and testing of alternative flow system conceptualizations but will illustrate repository siting issues related to spatial permeability distributions, uncertainty in fracture network geometries/properties, variably saline hydrogeochemical conditions and transient boundary conditions during glacial and peri-glacial conditions. Other current geoscience work program activities examining issues surrounding long-term flow system stability and groundwater flow system evolution include development of a Design Basis Glacier Scenario (Peltier, 2001), participation in the DECOVALEX III coupled thermal-mechanical-hydraulic modelling program (i.e. examining impact of transient hydromechanical boundary conditions during a glacial cycle on groundwater flow patterns/rates) (Chan and Stanchell, 2002) and the paleohydrogeologic Whiteshell Research Area Fracture Infill Mineral Assemblage Study (McMurry and Ejeckham, 2002). These activities are intent on providing a revised basis to explore and demonstrate long-term groundwater flow and hydrogeochemical stability in a Shield environ and, in so doing, provide evidence of groundwater residence times and flow patterns (i.e. potential changes in discharge zones).

References

Peltier, W.R., 2001, A Design Basis Glacier Scenario, Ontario Power Generation Report no. 06819-REP-01200-10069-R00.

Chan, T. and F.W. Stanchell, 2003, DECOVALEX III, BMT3 Glaciation Bench Mark Test, Phase I, Progress Report, Ontario Power Generation Report No. 06819-REP--1300-10060-R00.

McMurry, J and R. Ejeckam, 2002, Paleohydrogeological Study of Fracture Mineralogy in the Whiteshell Research Area, Ontario Power Generation Report No. 06819-REP-01200-10082-R00.

Sykes, J.F., E. Sudicky, M. Jensen, S. Normani and R. McLaren, 2002, Strategy to Assess Regional-Scale Flow and Transport from a Used Nuclear Fuel Repository in Fractured Crystalline Rock -Abstract Geological Society of America Denver Colorado October 2003.

4.02.14 System Performance - General - Vault-Induced Fracturing

PARTICIPANT COMMENTS

Conservation Council of New Brunswick

it is impossible to put waste into such a geologic formation without disturbing it through fracturing. [Comment 1988, Source Document ph3pub162, Page 2]

I'Union Sain-Laurent Grands Lacs

Il y a des incertitudes scientifiques qui subsistent tel la création de zones de fracture artificielles lors du creusage de la roche.

[There remain scientific uncertainties such as the creation of artificial fracture zones during excavation.] [Comment 1465, Source Document ph3pub194, Page 4]

Mouvement Vert - Mauricie

Will excavating the rock to create a network of vaults increase the risk of artificially creating a fracture zone in the rock? Weakened by the extraction, the rock would be more susceptible to cracking, thus creating a new fault line. Could an earthquake use the network of tunnels as a preferred route? Without weakening it, how can the rock be checked to ensure there are no fault lines in proximity to the repository? [Comment 1488, Source Document pub024, Page 25, Section 2.4.2]

Natural Resources Canada

Of potentially greater concern is the presence of a plane of weakness in the geosphere represented by the series of tunnels forming the disposal vault. This planar feature will be subject to a variety of stresses that might include those arising from excavation, residual stresses in the pluton, thermal stress and seismic events. The probability of a fault being generated by the presence of the vault, and possibly connecting the vault to other faults has not been addressed. As such a scenario could provide a high velocity conduit from the vault to the biosphere, its probability of occurrence should be considered. [Comment 769, Source Document ph2gov001, Page eng2]

There appears to be no consideration of the possibility that rock stresses may cause the EDZ under different rooms to link, forming a continuous high-conductivity carpet underlying a large portion of the vault area. Should this zone intersect an important fracture, it would act as a large drain, scavenging escaped radionuclides from all over the vault and channelling them towards the fracture. When modelling contaminant transport in low-permeability media, preferential flow paths for convective transport are an acute and ever-present concern. This issue could have been discussed in more detail in the EIS. [Comment 801, Source Document ph2gov001a, Page 08, Section 2.2.2]

Northwatch

the EIS should discuss the effect on the rock mass of a fracture having been created through engineering; specifically, the EIS should discuss the differences between natural and engineered faults, and how those faults will facilitate differently or similarly to the migration of water and radionuclides, and respond differently or similarly to catastrophic disturbances, such as earthquakes [Comment 1366, Source Document pub046, Page 13, Section d]

Northwatch (Lloyd)

Additional Key Information Deficiencies Identified in Phase II Technical Hearings (June 1996) ... - cracking on a horizontal plane around vault [Comment 1553, Source Document ph2tec045, Page 24]

Scientific Review Group

The AECL assumption of long-term geomechanical stability of the vault is unjustified. The SRG is of the opinion that the possibility of the development of large-scale fractures parallel to the plane of the vault, as a result of excavation-induced stresses and stress concentrations, should not be ignored. Under the high horizontal compressive in situ rock stress regime that is common in the Canadian Shield, the configuration of the vault, with its large horizontal extent, is conducive to fracturing. Stress changes due to the changing thermal regime, and long-term tectonic stress changes, could also play a role in the development of fractures. [Comment 353, Source Document tec004, Page 049, Section 6.2.3]

OPG RESPONSE

Rock mass stability has been studied by the Canadian geologic repository program for two decades and in the Canadian mining industry for much longer. The results of these studies indicate that it will be possible to construct an underground repository with minimal fracturing of the host rock (see Chandler and Read, 2000; Chandler and Read 2002).

OPG agrees this is an important consideration in the engineering design of a repository. Present work includes use of combined thermal-hydraulic-mechanical models to improve our ability to predict the response of the rock mass to the repository.

References:

Chandler, N., and R. Read. 2000. Thermal-mechanical stability studies project status - March 2000, OPG Report 06819-REP-01200-10030-R00.

Read, R.S. and N. A. Chandler. 2002. An approach to excavation design for a nuclear fuel waste repository - the thermal mechanical stability study final report. Prepared by RSRead Consulting Inc. and Atomic Energy of Canada Limited. Ontario Power Generation, Nuclear Waste Management Division Report 06189-REP-01200-10086-R01.

4.02.15 System Performance - General - Ease of Retrievability

PARTICIPANT COMMENTS

Scientific Review Group

different scenarios [variations in the position of the vault within the groundwater flow system] selected from a broad range of generic scenarios could have been compared with respect to ease of retrievability of the waste, in case the need were to arise in the future. [Comment 437, Source Document tec004, Page 079, Section 6.6.2]

OPG RESPONSE

The ease of retrievability of containers from an open or sealed repository should not be significantly affected by the groundwater flow system within the range of groundwater conditions expected for a repository environment.

The feasibility of the retrieval of used fuel containers from one conceptual repository design has been discussed by Acres et al. (1996), and is being addressed by a consultant CTECH for OPG in the 2003 update of a conceptual design of a deep geologic repository.

Reference:

Acres International Limited, SENES Consultants Ltd., SPAR Aerospace Ltd and Davey International. 1996. Feasibility of retrieval of nuclear fuel waste from a sealed disposal vault. Atomic Energy of Canada Limited report AECL TR-M-44.

4.02.16 System Performance - General - Open Borehole PARTICIPANT COMMENTS

Atomic Energy Control Board

The only non-disruptive scenario is of an open borehole extending from surface to the vault horizon (Postclosure PRD, p. 69). However, the evaluation of the open borehole scenario (Postclosure PRD, p. 258) is inadequate, in that only boreholes open to the surface are considered (instead of including all boreholes that pierce the assumed waste exclusion zone), no impact of failure of borehole seals to less than specification is included, and the assumption of low probability of occurrence is based on presumed but undemonstrated quality assurance procedures. [Comment 575, Source Document gov002, Page 27, Section B.1.2]

Campaign for Nuclear Phaseout

Forgetting to plug one single borehole, or not doing it perfectly, would be sufficient to cause a catastrophy in the near term.... a weak link such as a single unplugged borehole or an undetected fault or a poor interface between the cement and the wallrock would provide rapid passageways for radionuclides such as the very mobile iodine- 129 to reach surface very rapidly and contaminate the biosphere. We cannot afford to make a single mistake. Everything must be perfect and remain so for hundreds of thousands of years [Comment 1832, Source Document phpub104, Page 03]

Canadian Coalition for Nuclear Responsibility (Regroupement pour la surveillance du nucléaire)

Chacun de ces trous de sondage devient un passage futur possible pour les contaminants radioactifs qui pourraient s'échapper de la voûte. Comment garantir que tous ces trous seront scellés de façon parfaite?

[Each exploration borehole becomes a possible future pathway for radioactive contaminants to escape the vault. How can it be guaranteed that all these boreholes will be perfectly sealed?] [Comment 1905, Source Document ph3pub192, Page 2]

There are thousands of unlogged boreholes in the Canadian Shield. The proponent proposes to fill only those that it knows of. This is hardly a sufficient reason to exclude the possibility of unplugged boreholes from the scenarios. [Comment 1895, Source Document pub049, Page 40]

Northwatch (Lloyd)

Additional Key Information Deficiencies Identified in Phase II Technical Hearings (June 1996) ... - impairment of passive safety feature by borehole placement [Comment 1550, Source Document ph2tec045, Page 24]

Scientific Review Group

The open borehole scenario has been totally mishandled. The assertion that an open borehole passing as close as 5 m from a vault room would not contribute significantly to risk is based largely on indirect comparisons with transport from the vault through the exclusion zone to fracture zone LA1, and on the unsubstantiated assumption that the rock webs between the rooms will have a uniformly low permeability similar to the rock immediately above and below the vault. A mere 10% increase in rock web permeability above the nominal value would cause the AECB criterion to be reached. [Comment 522, Source Document tec004, Page 171, Section E-2.1.4]

OPG RESPONSE

OPG is planning to conduct a number of "what-if" scenarios to assess the robust nature of a deep geologic repository for used fuel. The impact of an open borehole extending from the surface to the vault is one scenario that would depend on the conditions at the particular site, especially the location

and hydraulic conductivity of major features near the vault and the density gradient of the groundwater due to salinity.

4.02.17 System Performance - General - Barrier Degradation PARTICIPANT COMMENTS

Atomic Energy Control Board

The scenarios examined using SYVAC do not include failures of the barriers, other than the container (Postclosure PRD, p. 257). None of the factors related to barrier failure in Table 4-2 (Postclosure PRD, pp. 58-63) such as cracking of the waste exclusion zone and buffer or degradation of shaft and drift seals, are incorporated in the SYVAC scenarios (Postclosure PRD, p. 68). [Comment 574, Source Document gov002, Page 27, Section B.1.2]

OPG RESPONSE

Failure of other barriers was not explicitly treated as a SYVAC scenario, as noted, although some degree of barrier degradation was considered as a result of the range of input parameters considered.

However, it is clear that it would be important in future assessments to explicitly consider a range of scenarios. The nature of these scenarios would likely develop in consultation with the stakeholders, such as CNSC or local communities. But considering degradation of other barriers would almost certainly be of interest. Consequently, various "defective barrier" sensitivity cases are explicitly considered in the most recent OPG Third Case Study safety assessment (Garisto et al. in prep.).

References:

Garisto, F. et al. In preparation. Third Case Study - Defective container scenario. Ontario Power Generation report 06819-REP-01200-10126-R00.

4.02.18 System Performance - General - Geosphere Discharge PARTICIPANT COMMENTS

Natural Resources Canada

The authors should also discuss the possible impact of catastrophic geological events, such as earthquakes, on rates of water flow and nuclide discharge across the interface. [Comment 716, Source Document ph2gov001, Page bio2]

OPG RESPONSE

In the Environmental Impact Statement and Second Case Study realisations of the used fuel repository concept, the effects of catastrophic events such as earthquakes were not explicitly examined. A focus for the Deep Geologic Repository Technology Program (DGRTP) is to re-examine this issue through field characterisation and numerical experiments that attempt to demonstrate longterm flow system stability that would span such catastrophic events. For example, work associated with the Apatite Fission Thermochronology (AFT) suggests that the Lac Du Bonnet Batholith has had a protracted history of sedimentation, burial (kilometers depth), erosion and uplift (Everitt and Osadetz, 2000). Despite this tectonic history the batholith still possesses a relatively simple fracture framework that would not be altered by geological events over the time scale relevant to repository safety. Paleohydrogeologic investigations, such as the Whiteshell Research Area Fracture Mineral Infill Case Study, continue to provide evidence that the flow system is able to maintain reducing conditions over long time periods. From a hydrogeochemical perspective, reasoned explanations for the origin of host rock matrix and fracture fluids at repository depths strongly suggest hydrogeologic processes and mechanisms occurring over extremely long time scales (Gascoyne, 2000). Evidence of variably dense fluids further support this contention in that groundwater flow system gradients and groundwater movement in such systems is stagnant and largely unaffected by large scale transients (i.e. glacial cycles, earthquakes).

The Deep Geologic Repository Technology Program continues to co-ordinate and advance site characterisation methods used in evaluating long-term flow system stability. Such tools coupled with numerical modelling provide a basis to address issues of conceptual flow system uncertainty and groundwater flow system dynamics that could influence sub-surface radionuclide migration and the environmental performance of a used fuel repository (Gierszewski et al., 2001).

References:

Everitt R. and K. Osadetz. 2000. Application of apatite fission track thermochronology to dating basement reactivation. Prepared by 1Atomic Energy of Canada Limited and 2Geological Survey of Canada for Ontario Power Generation. Ontario Power Generation, Nuclear Waste Management Division Report 06819-REP-01200-10040-R00. Toronto, Ontario.

Gascoyne, M. 2000. Hydrogeochemistry of the Whiteshell Research Area. Prepared by Gascoyne GeoProjects Inc. for Ontario Power Generation. Ontario Power Generation, Nuclear Waste Management Division Report 06819-REP-01200-10033-R00. Toronto, Ontario.

Gierszewski, P., S.B. Russell, F. Garisto, M.R. Jensen, T.F. Kempe, P. Maak and G.R. Simmons. 2001. Deep geologic repository technology program – annual report 2000. OPG NWMD Report 06819-REP-01200-10055-R00.

4.02.19 System Performance - General - Volcanoes

PARTICIPANT COMMENTS

Natural Resources Canada

Volcanoes are mentioned and dismissed in Table 4-1, p.56. Although the conclusions are probably valid, they would better have been placed in a probabilistic context than the unprovable statement "There are no hot spots on the shield at present." [Comment 774, Source Document ph2gov001, Page pos3]

OPG RESPONSE

In developing a safety case for the repository concept it will be necessary to demonstrate how longterm geologic stability of a host formation could influence repository performance. As part of the safety case, quantitative calculations will be performed to illustrate post-closure repository performance. The calculations, either deterministic or probabilistic, will consider scenarios related to the expected evolution of the repository and 'what if' type analyses that demonstrate robustness of design (i.e. glacial and peri-glacial conditions). These calculations will be supported by performance assessment field studies that provide evidence of geologic and flow system stability on a time frame of 10,000's to 100,000's years (or longer). Beyond this time frame reasoned geologic and safety arguments will be used to evaluate the certainty and relevance of disruptive events on repository performance. Disruptive geologic events, such a volcanism, would be addressed based on current scientific knowledge with regard to their time and space of likely occurrence, influence on repository barrier systems and the critical group. Such evaluations would be subject to peer review and a comparison with international practice.

4.02.20 System Performance - General - Contaminants in Fuel

PARTICIPANT COMMENTS

Campaign for Nuclear Phaseout

The EIS does not provide an adequate description of the toxic non-radioactive fuel components. The issue is mentioned, but no details are provided on the nature of the non-radioactive toxic materials. [Comment 1823, Source Document pub027, Page 35, Section III.H]

Health Canada

As far as can be seen, no mention is made of the risks associated with the presence of nonradiological contaminants in the very long term scenario. [Comment 972, Source Document gov006, Page 19]

The EIS lists antimony, bromine, cadmium, cesium, chromium, molybdenum, samarium, selenium, and technetium as elements also present in the spent fuel bundles.... the section fails to identify potential exposure scenarios and concentrations of each which might be found in air, soil, or water. An appropriate model might provide a range of concentrations of each contaminant for a variety of release scenarios. [Comment 995, Source Document ph2gov011, Page 10]

Mouvement Vert - Mauricie

The biological effects of toxic chemicals, described in Section 2.1.9, are insufficiently described and make it impossible to assess the danger of the chemicals contained in irradiated fuel. [Comment 1487, Source Document pub024, Page 25, Section 2.4.1]

Nuclear Awareness Project

[Provide] detailed information about the content and health impact of non-radioactive hazardous elements and compounds in nuclear fuel waste [Comment 2149, Source Document pub035, Page 4, Section B]

Scientific Review Group

No quantitative information is provided for any aspect of chemical toxicity in the biosphere from nuclear fuel waste. The SRG must conclude that AECL is convinced that non-radiological contamination is of no concern. If this is the case, the evidence or information for such a position should have been presented. [Comment 416, Source Document tec004, Page 068, Section 6.4.2]

AECL's treatment of chemical toxicity is cursory; there is no mention of chemical toxicity to humans in the EIS. An evaluation of chemically toxic elements in the postclosure assessment document led to the conclusion that there would be no significant chemical toxicity effects to members of the critical group (R-Postclosure 1994: p.205). Chemical toxicity of an element is generally a function of the chemical form it is in. The effect of chemical form was not discussed. It is not clear whether the natural variability of background concentrations of chemical elements included some abnormal environmental conditions. [Comment 458, Source Document tec004, Page 084, Section 6.6.5]

The consideration of chemical toxicity in R-Biosphere is inadequate.... The statement that: "Insufficient data are available to decide on compensation, additivity or synergism of effects" (R-Biosphere 1993: p.11) and thus that it is difficult to develop a common assessment approach for chemical toxicity with that used for radiological effects is not sufficient reason for not giving attention to chemical effects. Indeed, the absence of data makes careful consideration more important until it can become clear that toxic chemicals will not reach or traverse the biosphere. The statement that no dosimetric procedures are available that could lead to calculations of doses to humans (R-Biosphere 1993: Section 1.3.1, p.11) is not correct; there are well established methodologies for this.... There is no discussion of how chemical toxins released from the vault would be regulated in surface water and soil; and there is no treatment of toxic chemical concentrations in the BIOTRAC equations [Comment 495, Source Document tec004, Page 231, Section H-2.2]

OPG RESPONSE

The chemically toxic contaminants of concern and their inventories are listed in Table 5-3 of the Postclosure Assessment report (Goodwin et al. 1994). Identification of these elements was based on the screening study by Goodwin and Mehta (1994). The predicted releases of the potentially toxic contaminants are also provided in the Postclosure Assessment report for both the median case simulation (Table 6-1 in Goodwin et al. 1994) and the probabilistic simulation (Section 6.5.3 in Goodwin et al. 1994).

The predicted concentrations of the chemically toxic contaminants in the biosphere are listed in Table 6-8 of Goodwin et al. (1994). The largest predicted concentrations are for Sb and Br. The potential environmental effects of these 2 elements are not explicitly evaluated but are indirectly shown to be small by comparing the predicted environmental concentrations with background concentrations of these elements. Because the predicted concentrations of the chemically toxic contaminants are very low compared to their background concentrations, no explicit evaluation of the health risk resulting from exposure to the chemical toxic contaminants was carried out in the EIS.

The calculation of chemical concentrations in soil, water and air will be added to CC4/BIOTRAC. Further review and assessment of chemical toxicity is also planned.

Reference

Goodwin, B.W. and K.K. Mehta. 1994. Identification of Contaminants of Concern for the Postclosure Assessment of the Concept for the Disposal of Canada's Nuclear Fuel Waste. Atomic Energy of Canada Limited Report AECL-10901.

4.02.21 System Performance - General - Mining-Induced Seismicity PARTICIPANT COMMENTS

Canadian Geotechnical Society

the EIS documents make no reference to the possible occurrence of mining induced seismicity effects or how these would be controlled. The concerns here are the possibility of induced rock fracturing around the caverns and emplacement boreholes. This could increase rock permeability somewhat in regards to groundwater movement and could possibly cause minor rock bursts during the excavation stage if rock conditions are especially complex, with high and unbalanced in situ stress, a high recovery ratio of excavated to supporting rock occurs and also if rapid excavation techniques are employed. [Comment 1101, Source Document pub020, Page 12]

OPG RESPONSE

OPG believes that the impact of mining induced seismicity on a deep geologic repository would be very small since one of the technical factors for site screening is "no known current valuable mineral resources or likely future resources" (see Davison et al. 1994, The disposal of Canada's nuclear fuel waste: Site screening and site evaluation technology, AECL-10713, COG-93-3, page 58). At the URL, Ortlepp assessed the rock burst risk to be minimal (Ortlepp, W.D. (Steffen, Robertson & Kirsten Consulting Engineers). 1992. Assessment of rockburst risk in the Underground Research Laboratory - Pinawa, Manitoba, Canada. Contractor's report to Atomic Energy of Canada Limited, designated as TR-M-12). Studies at the URL have indicated that underground openings can be designed to minimise excavation-induced rock fracturing (see Chandler and Read, 2000, Thermal-mechanical stability studies project status - March 2000, OPG Report 06819-REP-01200-10030-R00). The affect of heat on excavation-induced rock fracturing has also been studied at the URL (see Read, R.S., J.B. Martino, E.J. Dzik, S. Oliver, S. Falls and R.P. Young. 1997. Analysis and interpretation of AECL's Heated Failure Tests. Ontario Hydro Report 06819-REP-01200-0070-R00).

These studies indicate that the effect the expected temperature rise in the rock, less than 85 C, will not result in significant changes in the rock mass that would affect long-term safety of a geologic repository.

4.02.22 System Performance - General - Contaminant Speciation

PARTICIPANT COMMENTS

Chemical Institute of Canada

The chemical species of the radionuclides must be discussed and studied. After all it is the chemical form of the species that finally dictates if and how the radionuclide will move in the biosphere. [Comment 1110, Source Document tec005, Page 04, Section I.1.4]

Scientific Review Group

BIOTRAC does not directly trace the chemical form in which any radionuclide may be present in each stage of its journey from the geosphere to the biological end point. It is stated that the parameter values adopted for transport calculations " ... are representative of the most mobile form of each nuclide in the environment" (R-Biosphere 1993: p.41). The means by which the most mobile form is determined or selected is not revealed. Inasmuch as the chemical species plays an important role in the sorption of radionuclides on other minerals or particles, on colloids, or in their involvement in biological processes with consequent acceleration or retardation of transport, the identification of chemical form could be important. [Comment 284, Source Document tec004, Page 236, Section H-2.3]

OPG RESPONSE

It is true that the chemical form of a radionuclide affects how the nuclide moves. This is taken into account implicitly in the EIS. For example, migration through the biosphere is described based on experimentally derived data such as soil-to-plant transfer factors. Thus, if the experiments from which the data were obtained are representative of the conditions and biospheres considered in the EIS, then these transfer factors are also applicable in the EIS biosphere, without needing to know the chemical speciation of the radionuclide. Similarly, the parameter values for nuclide transport in the container, buffer, backfill and geosphere all were selected considering the materials and conditions expected in the repository relative to the experimental conditions. Furthermore, the variation in conditions is approximately accounted for by use of distribution functions for these parameters.

In the EIS, however, the phase of the nuclide (gas, dissolved species) is taken into account in the determination of nuclide migration through the biosphere. For example, for I-129, account is taken of I-129 volatilization from soil and water bodies in the calculation of I-129 air-borne concentrations.

For any future OPG safety assessment, the treatment of contaminant speciation is identified in the corresponding FEP Database, #3.2.02 Speciation and Solubility (e.g. Garisto et al. In prep).

References

Garisto, F. et al. In preparation. Third Case Study - Features, Events and Processes. Ontario Power Generation Report 06819-REP-01200-10125-R00.

4.02.23 System Performance - General - Consideration of Other Waste PARTICIPANT COMMENTS

Canadian Coalition for Ecology, Ethics and Religion

Disclose all information about AECL's proposal to the US DOE to irradiate WPu in CANDU reactors as MOX fuel, and the effects of the resulting spent MOX fuel on the design and performance criteria of the UFDC. [Comment 1849, Source Document ph2pub011, Page 1]

Resolve contradiction: a key requirement of WPu in MOX fuel scheme is to make WPu permanently irretrievable, which is inconsistent with AECL's claims that the vault will be reparable, its contents retrievable. [Comment 1851, Source Document ph2pub011, Page 1]

The higher Pu content in spent MOX fuel would give it a higher potential for achieving criticality accidentally. (RO p. 363). [Comment 1857, Source Document ph2pub021, Page 68, Section 10.4.5]

If the MOX fuel proposal were to go ahead there would no longer be any possibility of retrieving used fuel from the proposed vault. The intention of the disposal process for nuclear disarmament purposes can only be met by making the plutonium permanently unavailable. Also irradiated MOX fuel would be so radioactive that any attempt to reopen the vault after it was sealed would risk unacceptable releases of radionuclides. [Comment 1858, Source Document ph2pub021, Page 68, Section 10.4.6]

the EIS is based on spent uranium oxide fuel, and presents no evidence to show the design of the vault is adequate to handle spent MOX fuel containing up to three and a half times as much plutonium as is found in spent uranium oxide fuel [Comment 1859, Source Document ph2pub021, Page 69, Section 10.4.7]

As Canada became an active participant in the post-Cold War clean-up of the nuclear weapons leagcy ... it would have to incur the attendant problems and cost, which include increased risks to human and environmental health and safety associated with the ... potential burial in the proposed vault of used MOX fuel; the threat of becoming a target for states wanting to acquire nuclear weapons materials; and the militarization of safeguards and security measures. [Comment 1860, Source Document ph2pub021, Page 70, Section 10.5.1]

the ability of ... either proposed vault design to meet the requirements for the safe disposition of nuclear fuel wastes of different characteristics is a concern and evidence has yet to be presented that this requirement can be met within the same vault design. [Comment 1874, Source Document ph3pub160, Page 9]

The possibility for criticality should be calculated for at least two other situations with respect to spent CANDU fuel ... 2) where the plutonium content of the spent fuel is increased by the use of MOX fuel in CANDU reactors and subsequent emplacement in a geologic repository. [Comment 2147, Source Document phpub043, Page 25, Section 09]

AECL's proposal to burn WPu in MOX fuel raises technical ... issues concerning the disposal concept [Comment 1846, Source Document phpub043, Page 42, Section 16]

Concerned Citizens of Manitoba

There are significant questions about whether AECL's proposal is for a repository for Canadian waste, or for the potential importation of waste from other countries.... this level of uncertainty ... [is] unacceptable for an environmental review in which the public is called upon to give an opinion. [Comment 1956, Source Document phpub153, Page 5]

We can find no analysis of the differences in need for storage, treatment or disposal processes if the disposal site is to include high-level waste from other countries which use other nuclear generation processes and therefore have waste which is different from CANDU waste. There is only a brief mention of the different disposal requirements if AECL and the nuclear utilities develop and implement other processes within the Canadian system (for instance mixed oxide [MOX] fuel use within CANDU reactors.) [Comment 1952, Source Document pub034, Page 5]

there is no reference to [waste from light-water reactor systems] in the extremely brief section on the danger of waste reaching a critical mass (p 115). Potential criticality has been identified as a danger by scientists working on disposal systems in New Mexico for the US Department of Energy. [Comment 1953, Source Document pub034, Page 5]

Concerned Citizens of Renfrew County

Don't regard high-level fuel wastes in isolation - examine all radioactive wastes and prioritize action based on threats to human health and the environment [Comment 1975, Source Document phpub171, Page 3]

Energy Probe (Rubin)

One change in nuclear power technology which is currently being proposed by Ontario Hydro and AECL to the U.S. government is the fissioning, in Canada (probably at the Bruce-A Nuclear Generating Station) of fuel containing weapons-grade Plutonium from U.S., or possibly former Soviet, nuclear weapons.... Further, in all current proposals discussed in public, the resulting nuclear fuel waste would remain in Canada. This proposal could therefore change both the quantity and the nature and characteristics of the nuclear fuel waste awaiting disposal in Canada. The EIS documents do not discuss these changes, or their impact on the concept. [Comment 2060, Source Document pub014r, Page 7]

Inter-Church Uranium Committee

The transportation and management of nuclear fuel wastes from other countries presents a range of direct and indirect risks to Canadians because of their radioactivity and longevity. [Comment 2113, Source Document ph3pub018, Page 4]

Joint Committee of the Canadian Academy of Engineering and the Royal Society of Canada

This evaluation of the concept has assumed that only Canadian waste is being placed in Canadian repositories, but the Committee recognizes that a superior Canadian process may result in Canada being approached to dispose of waste from other countries. How that may affect the design or operation of the Canadian repository is not clear. [Comment 1195, Source Document phpub031, Page 6]

Northwatch (Kock)

criticality accident scenarios must be given serious consideration now that MOX fuel is proposed for use in Canada. A full range of criticality accident scenarios involving spent MOX fuel should be assessed in detail to illustrate the impacts, the likely remedial measures needed, as well as preventative measures to be implemented at all stages of used MOX fuel handling, storage and proposed burial. Other waste forms including used fuel from research reactors located in Canada and liquid high level wastes (presently owned by AECL) should be assessed is a similar manner in this regard. [Comment 1561, Source Document ph3pub096, Page 03]

An important consideration, given Canada's motivation for agreeing in principle to import MOX fuel, is the question of long-term security of the plutonium in spent MOX fuel bundles (and all spent fuel for that matter) in terms of its isolation from anyone or any group of people who wishes to use the plutonium to make nuclear weapons. This applies to the present, and perhaps more-so to the future, since the radiological barrier which makes the spent fuel standard attractive to policy-makers now, will decay long before the plutonium itself decays. This may have implications for how decisions are made to transfer information about the contents and locations of the proposed burial vault to future generations.... The Panel should find that because the AECL proposal includes a clear intention to pass detailed information to future generations about the contents and location of the proposed burial vault, that the intent of spent fuel standard cannot be met once the radiological barrier decays. [Comment 1562, Source Document ph3pub096, Page 04]

The co-proponents have not provided sufficient information on the topic of spent MOX fuel heat generation trends [Comment 1563, Source Document ph3pub096, Page 05]

AECL's Environmental Impact Statement (EIS) does not discuss the use of MOX fuel made from weapons-grade plutonium in the context of the proposal to import this type of fuel from the U.S. and Russia. [Comment 1560, Source Document ph3pub096, Page ES-1]

Nuclear Awareness Project

A complete inventory of all intermediate and high level nuclear wastes in the country, including all nuclear fuel waste, reactor core components, existing and future liquid and solidified wastes from reprocessing, etc. must be fully disclosed in order to better determine which waste management options may be most appropriate. [Comment 1620, Source Document cs018, Page 2]

OECD/NEA Review Group

as the Canadian programme progresses, attention should be given to other types of non-standardised CANDU fuel bundles. For example, the Group recalls that, in the past, a limited number of fuel rods was manufactured with a gas plenum and, therefore, with a non-collapsible sheath. [Comment 1199, Source Document tec001, Page 06, Section 3.1.1]

Planetary Association for Clean Energy

no consideration has been given to: 1) the actual de-commissioning of nuclear power plants; 2) what to do with radioactive concrete and metals from de-commissioned nuclear power plants; and, 3) the other different types of radioactive waste. [Comment 1647, Source Document pub029, Page 04]

United Church of Canada

The possibility that ...the irradiated spent fuel from reactors using mixed-oxide fuel would be part of the waste stream in a deep burial concept, increases the potential for criticality [Comment 2148, Source Document phpub124, Page 3-20, Section 3]

Since it is possible that the Concept could have to deal with spent MOX fuel, the interim storage, transportation, security, safety, environmental and health risks, long-term storage or disposal, retrievability, etc. have to be evaluated for that scenario to know if it would be feasible for the Concept to meet the requirements. [Comment 1748, Source Document phpub124, Page 3-28, Section 3]

OPG RESPONSE

OPG's studies have focussed on natural uranium fuel in CANDU reactors in Canada. If Canada ever produces used MOX fuel, the repository arrangement will have to be assessed and perhaps modified to ensure that all design criteria are met for the characteristics of the used MOX fuel. The safety of the deep geologic repository will not be compromised.

4.02.24 System Performance - General - Migration by Erosion PARTICIPANT COMMENTS

PARTICIPANT COMMEN

Northwatch (Willis)

AECL has not fully considered the impact of groundwater inundation on these barriers, ie. although radionuclides may be absorbed, the material onto which they are absorbed may itself be transported out of the vault and rock, and into the biosphere. [Comment 1565, Source Document ph3pub096a, Page 08, Section 4]

OPG RESPONSE

The characteristics that would be favoured for a repository site include large bodies of sparsely to moderately fractured rock bounded by fracture zones, which have low hydraulic permeability. If a site had these characteristics it is very unlikely that there would be an "inundation" of groundwater. Rather, groundwater would move very slowly along fractures and would not cause significant erosion of the sealing materials in the vicinity of the nuclear fuel waste containers. The transport of colloids and other macroscopic materials, and any radionuclides attached to these materials, in the low permeability rock mass expected at the site of a deep geologic repository is expected to be negligibly small. (Further, clay particles that may detach at the buffer/geosphere interface are likely to interact with common fracture minerals and so not travel far (Pusch 2001, p.128)).

Reference

Pusch, R. 2001. The buffer and backfill handbook, Part 2: Materials and Techniques. SKB Technical Report TR-02-12.

4.02.25 System Performance - General - Meteorite Impact

PARTICIPANT COMMENTS

Durham Wetlands and Watersheds

Discussion of Meteoritic Impacts in the EIS is cursorial. The EIS does not include discussion of recent research which suggests that meteors come to Earth more often in pairs and swarms than singly, the Earth may bear cratering belts with nodes, and comets may excavate craters as large as those of meteors... in light of recent research of meteoritic impacts and meteors in pairs and swarms, and these impacts occurring along cratering rings, the Facility should hence be located away from these rings and at least 1 km or more beneath the Earth's surface. [Comment 1999, Source Document pub043, Page 3]

OPG RESPONSE

The impact of meteors on a hypothetical deep geologic repository in plutonic rock has been calculated to be very small in AECL's 1994 EIS (Wuschke et al. 1995). Further review of this would be conducted during the safety assessment of a real potential site for a repository. See the corresponding FEP Database discussion, #1.5.01 Meteor Impact (e.g. Garisto et al. In prep. for the Third Case Study).

References:

Garisto, F. et al. In preparation. Third Case Study - Features, Events and Processes. Ontario Power Generation Report 06819-REP-01200-10125-R00.

Wuschke, D. et al. 1995. Assessment of the long-term risk of a meteorite impact on a hypothetical Canadian nuclear fuel waste disposal vault deep in plutonic rock. AECL Report AECL-11014.

4.03.01 System Performance - Vault - General

4.03.01.01 System Performance - Vault - General - Gas PARTICIPANT COMMENTS

Environment Canada

AECL has failed to address ... the migration of radionuclides due to gaseous transport or to gas-driven hydrologic transport (despite the fact that the repository will be gas-filled on closure) [Comment 851, Source Document gov003, Page 20, Section 2.9]

AECL does not adequately address the possible entrapment of a pressurized room air bubble, and its consequences regarding radionuclide release to other areas of the repository that may be operational, and eventually to the biosphere via gas-driven two-phase flow from the repository, or via gaseous transport. Gas production within the vault is possible even if no water enters from the surrounding rock. It could occur from the breakdown of organic material within the backfill, from containers that have failed as a result of manufacturing defects, and possibly from gamma-radiolysis of moisture in the buffer. [Comment 861, Source Document gov003, Page 21, Section 2.10]

Partial saturation could lead to even less favourable conditions under which containers breached by corrosion could release volatile nuclides (e.g. 1291), and gas could be produced by alpha-radiolysis before a complete sealing of the buffer and backfill by saturation-induced swelling had occurred. [Comment 863, Source Document gov003, Page 22, Section 2.10]

Calculations conducted by the Subsurface Advisory Team indicate that, following resaturation, significant quantities of gas may be generated in the repository by radiolysis, corrosion, groundwater degassing and organic matter degradation. These calculations indicate that gas pressures may, but not necessarily will, exceed confining pressures so that two-phase flow may occur in the repository. If such were the case, it would be extremely difficult to estimate the fate of radionuclides leached from the waste containers and a performance assessment based on single-phase flow would be rendered questionable. [Comment 865, Source Document gov003, Page 24, Section 2.12]

the integration of gas generation and fate into the overall postclosure analysis, even at long times, has not been done. [Comment 866, Source Document gov003, Page 24, Section 2.12]

there were also several issues that were not adequately addressed ... the potential effects of gas generated or trapped during the post-closure period on radionuclide migration, and on the performance of the grouts and seals [Comment 870, Source Document gov003, Page 27, Section 2.13]

Northwatch (Lloyd)

Additional Key Information Deficiencies Identified in Phase II Technical Hearings (June 1996) ... - hydrogen gas formation from carbon steel corrosion in an anoxic condition [Comment 1551, Source Document ph2tec045, Page 24]

OECD/NEA Review Group

Owing mostly to the decision not to employ iron-based materials in the waste package, gas generation and two-phase flow were not dealt with quantitatively in the safety assessment. The Group felt that it would be prudent and would help retain flexibility to deal with these issues if bounding calculations were presented to support the purely qualitative assertions. [Comment 1209, Source Document tec001, Page 09, Section 3.1.4]
Scientific Review Group

Little attention ... has been paid to the potential formation of gases from organic sources.... Buffer material ... will contain 0.15% organic carbon... backfill material will contain 0.3% organic carbon ... Additional quantities of hydrocarbons will accumulate upon most rock, buffer and backfill surfaces ... from blasting and the use of diesel-powered underground equipment.... Assessment of potential inventories of carbon-based materials from all sources should have been made, and studies of CH4 and CO2 generation should have been performed ... gases could create the conditions for two phase transport, and contribute excess pressure. [Comment 227, Source Document tec004, Page 207, Section F-2.2.2]

OPG RESPONSE

There are four basic sources of gas in the vault: (1) air trapped in the vault at closure; (2) gas generated from buffer/backfill materials, notably from microbes using the residual levels of organics; (3) gas generated by corrosion of the containers and any external residual metals in the vault; and (4) gas generated within the containers, notably by corrosion of steel components or radiolysis of water.

While gas generation and transport remains an active question for LLW and ILW repositories, it is a secondary concern for deep geologic disposal of used fuel as considered in the Canadian concept. Multi-year field experiments (e.g., Isothermal Test, BCE) indicate that the trapped air is resorbed into the water or consumed during the resaturation process; microbial gas generation in buffer/backfill materials is slow; and corrosion of the reference copper containers is also slow. For the few containers that are assumed to fail early, the resulting gas generated within the container can in fact delay the radionuclide release of the container (e.g. SR97 reference canister defect scenario).

The topic of gas generation and transport continues to be studied as part of the international long-term waste management program of many countries. A recent assessment of our knowledge is provided in Rodwell et al (1999). OPG will continue to maintain an awareness of this issue. The suggestion for a set of bounding calculations on gas generation and transport within the Canadian concept is noted.

References

W.R. Rodwell, A.W. Harris, S.T. Horseman, Ph. Lalieux, W. Muller, L.O. Amaya and K. Pruess. 1999. Gas migration and two-phase flow through engineered and geological barriers for a deep repository for radioactive waste: Status report. OECD/NEA report. To be published.

SKB. 1999. Deep repository for spent nuclear fuel, SR97 - Post-closure safety. SKB Technical Report TR-99-06.

4.03.01.02 System Performance - Vault - General - Sand Annulus PARTICIPANT COMMENTS

Scientific Review Group

No description of the planned silica layer density state has been presented, nor does it appear feasible that a compacted, high density silica barrier can be emplaced.... The engineering functions of the silica layer have not been adequately presented. [Comment 33, Source Document tec004, Page 121, Section B-2.1.6]

the silica layer would represent a soft or deformable inclusion which could permit container settlement, container tilting, or some combination of both.... The sand annulus provides a significant layer around the container that could cause problems to the integrity of the system as a result of processes such as: cycling of hydration-dehydration of sand during saturation of the vault and buffer; irregular thermal conductivity; migration of clays into the sand layer; and focused sites for microbial activity. [Comment 514, Source Document tec004, Page 121, Section B-2.1.6]

The role of the sand annulus, within the system of engineered barriers as a whole, is not explained adequately. The potential effects that may be created by the sand in contact with the container and the buffer have not been addressed. Issues that should have been investigated include: the presence of residual air, the presence of significant void space; the interaction between the buffer and the sand, such as extrusion of buffer material into the sand through swelling; and the possibility of microbial activity. [Comment 225, Source Document tec004, Page 206, Section F-2.2.1]

OPG RESPONSE

The composition of the gap backfill material in the annulus between the container and the buffer material has evolved from:

- graded dry sand, to

- 50% sodium-bentonite prills and 50% fractionated silica sand or glass beads (e.g., ballotini), to

- 100% sodium bentonite pellets (Russell and Simmons 2003).

The material will be placed by gravity feed and the presence of the bentonite pellets will provide swelling potential as the gap backfill saturates with groundwater to ensure the gap is adequately filled. The gap backfill will provide a thermally conductive media to transfer heat away for the container into the buffer.

OPG is conducting engineering studies to assess the impact of the planned gap backfill layer surrounding a used fuel container in a deep geologic repository (see Baumgartner 2000).

References:

Baumgartner, P. 2000. Elemental composition of disposal vault sealing materials. OPG Report 06819-REP-01300-10015-R00.

Russell, S.B. and G.R. Simmons. 2003. Engineered barrier systems for a deep geologic repository in Canada. Presented at the 10th International High-Level Radioactive Waste Management Conference, March 30 - April 3, 2003, Las Vegas.

4.03.01.03 System Performance - Vault - General - Mechanical Support PARTICIPANT COMMENTS

Scientific Review Group

Mechanical support will likely be required to keep excavations stable and safe during construction and operation. The consequences of these supports and their emplacement to the long-term stability of the vault and the integrity of the surrounding rock mass should have been addressed in more detail. [Comment 467, Source Document tec004, Page 091, Section 7.3]

In order to mitigate hydrogen gas generation, AECL has suggested ... using stainless steel rather than normal carbon steel for vault support components, such as rockbolts (R-Vault 1994: p.30). Stainless steel bolts presently do not exist at full commercial scale. The long term response of stainless steel bolts to stress/strain conditions which may be encountered in-situ may be significantly different from that of conventional carbon-steel ones. [Comment 226, Source Document tec004, Page 206, Section F-2.2.2]

OPG RESPONSE

In 2002, OPG completed its multi-year study into the thermal-mechanical stability of underground excavations in granite (Read and Chandler 2002). The research suggests that stable rock openings can be constructed in granite and the stability of these excavations can be monitored and modelled using existing technology and codes.

Additional detailed studies on rock mass stability for underground openings and the required mechanical support would be conducted in the detailed engineering studies for a deep geologic repository, as part of the normal site-specific evaluation and assessment process.

References:

Read, R.S. and N. A. Chandler. 2002. An approach to excavation design for a nuclear fuel waste repository - the thermal mechanical stability study final report. Prepared by RSRead Consulting Inc. and Atomic Energy of Canada Limited. Ontario Power Generation, Nuclear Waste Management Division Report 06189-REP-01200-10086-R00.

4.03.01.04 System Performance - Vault - General - Radiolysis PARTICIPANT COMMENTS

Atomic Energy Control Board

the radiolysis dissolution model of Werme is considered by AECL to be too conservative, but the "compelling evidence" for this position that is referred to in the EIS is not provided (Vault PRD, p. 239). Werme's fractional dissolution rate of 10-5 to 10-4a-1 for the spent fuel is much greater than the 10-7 a-1 rate predicted by Shoesmith and Sunder (1991). [Comment 639, Source Document gov002, Page 58, Section C.3.1(iv)]

Chemical Institute of Canada

some account should be taken of the effects of alpha radiation during what will likely be a very long exposure of the waste form to ground water. [Comment 1115, Source Document tec005, Page 08, Section II.i.A]

Scientific Review Group

Radiolysis of water is not treated in sufficient detail [Comment 32, Source Document tec004, Page 120, Section B-2.1.5]

OPG RESPONSE

At the time of the EIS, it was believed that the redox potential at the fuel/groundwater interface would be controlled by the groundwater redox potential, which in turn would be controlled by the iron minerals present in the geosphere. That is, the effect of radiolysis was assumed to be small. Under these conditions, the dissolution of the fuel could be described using a solubility limited dissolution model (Johnson et al. 1994). In this model, there is no surface kinetic limitations to the rate of UO2 dissolution.

In the SCS, however, a kinetic dissolution model, based on electrochemical principles and more recent experiments, was used to calculate the rate of fuel dissolution (Johnson et al. 1996).. In this case, the rate of fuel dissolution was controlled by the corrosion potential at the fuel/groundwater interface. The corrosion potential, in turn, was dependent on the gamma, beta and alpha radiation field strengths. At early times (less than about 200 years) gamma and beta radiolysis effects dominate and average dissolution rates during this period are high (fractional dissolution rates of 0.0001/a). At later times alpha radiolysis effects dominate, and dissolution rates are small. This model predicted that, on average, more than 10 million years would be needed to dissolve all the used fuel in the vault

In future assessments, it is anticipated that this kinetic fuel dissolution model, in which the dissolution rate is dependent on the radiation field strengths, would be used to predict the rate of fuel dissolution (Kolar et al. 2000).

The other possible effect of water radiolysis is the generation of H2 and O2 gases. This will not be significant outside the container because the radiation fields will be low. Inside a failed container, the O2 generated is expected to be consumed in corrosion of the fuel or the inner iron vessel, leaving a buildup of H2 gas that would reach some steady state, with a balance between the generation rate, the loss through the buffer, and recombination back into water (SKB 1999, P. 32, 151).

References

Johnson, L.H., D.M. LeNeveu, D.W. Shoesmith, D.W. Oscarson, M.N. Gray, R.J. Lemire and N.C. Garisto. 1994. The disposal of Canada's nuclear fuel waste: The vault model for postclosure assessment. Atomic Energy of Canada Limited Report AECL-10714.

Johnson, L.H., D.M. LeNeveu, F. King, D.W. Shoesmith, M. Kolar, D.W. Oscarson, S. Sunder, C. Onofrei, and J.L. Crosthwaite. 1996. The disposal of Canada's nuclear fuel waste: A study of postclosure safety of in-room emplacement of used CANDU fuel in copper containers in permeable plutonic rock. Volume 2: Vault model. Atomic Energy of Canada Limited Report AECL-11494-2.

Kolar, M., D.M. LeNeveu and F. King. An interim performance assessment model for used fuel. OPG Report 06819-REP-01200-10034-R00.

SKB. 1999. SR97 Processes in the repository evolution. SKB Technical Report TR-99-07.

4.03.01.05 System Performance - Vault - General - Transients PARTICIPANT COMMENTS

Atomic Energy Control Board

The assumption that short-term transients will not affect the long-term safety (Postclosure PRD, p. 10) is not supported adequately. The long-term assessment adopts instantaneous loading, instantaneous resaturation and uniform thermal and stress initial conditions. The assumption that the sequential excavation, disposal and backfilling operations and the resulting non-uniform transient conditions in temperature, saturation and stress do not degrade any of the engineered barriers in the vault or the waste exclusion zone is presented without adequate supporting analyses. [Comment 573, Source Document gov002, Page 26, Section B.1.1]

extending the range of parameter values to include possible changes that may occur does not examine the evolution of the site or the seals. This approach, which only allows the assessment of different steady-states and not the transient conditions between steady-states, has not been shown to be appropriate for a risk analysis. [Comment 2153, Source Document gov002, Page 41, Section C.1.1(iii)]

Hare, Driedger, Jennekens, Rogers, and Shemilt

Among the subjects of concern are ... the assumption of instant vault saturation [Comment 1402, Source Document phpub150, Page 4]

Natural Resources Canada

Section 8.4 presents a study of possible consequences of early container failure. The time period considered (first 50 years after emplacement) is precisely that when unsaturated conditions prevail in the buffer material (3.2.1) and when the excavation damaged zone surrounding the buffer material is most likely to provide a high-conductivity flow path (3.2.1, 3.2.3) for radionuclide migration. These complicating yet possible critical factors do not appear to have been considered in the analysis. [Comment 728, Source Document ph2gov001, Page vau6]

In section 3.3 (pages 11-13) on the Presaturation Period, there is still no mention of the moisture retention characteristics of buffer and backfill materials ... During this period, these materials undergo a thermally-driven desaturation followed by a hydraulically-driven resaturation. Given the hysteresis in capillary pressure-saturation curves, the ultimate moisture contents of the buffer and backfill may be quite different from original values. Moisture content in the buffer material surrounding the canister is an important factor in container failure and radionuclide escape models. The physical and chemical processes operating during the presaturation period are quite complex and have been addressed by the proponent in a mainly qualitative way. [Comment 821, Source Document ph2gov015, Page 05]

Northwatch

the EIS's presentation that "because the buffer and backfill would have very low permeability, it would take several years to several thousand years for them to become saturated with groundwater, depending on the hydraulic properties of the surrounding rock." (pg. 83) should be extended to include a discussion of the hydraulic properties of effect, and how the applicable time frame ... would be determined in the site investigation stage, and how the time frame would affect site acceptability [Comment 1371, Source Document pub046, Page 14, Section d]

Northwatch (Lloyd)

Deficiencies Which Emerged or Remain Outstanding After Discussion in the Phase II Tehncial Hearing Sessions ...

- saturation and desaturation of repository and the shrink/swell effect on various buffer materials [Comment 1539, Source Document ph2tec045, Page 22]

OECD/NEA Review Group

In common with other national programmes, the behaviour of the backfill/buffer during the so-called "resaturation phase" of the repository is not directly evaluated, and instant resaturation upon closure is assumed. Further work will inevitably be necessary for a specific safety submission and might form part of the future work programme. In particular, resaturation calculations would be useful for the strengthening of the safety case given that re-saturation times could be significant compared to the 10{4} years regulatory compliance period and that uneven wetting could have an influence on canister stresses, caused by heterogeneous swelling pressures. [Comment 1204, Source Document tec001, Page 08, Section 3.1.3]

The transient resaturation period, which will commence immediately after repository closure, is not well understood, could be quite long and may induce significant effects in terms of the evolution of the engineered barrier system. It is currently not included in the performance assessment modelling and, although this approach is also adopted at present in most other countries, future work should aim to characterise the resaturation process in more detail. [Comment 1250, Source Document tec001, Page 17, Section 5.2]

Scientific Review Group

a long resaturation period (of the order of 1000 years), and also non-uniform resaturation, may have unfavourable consequences for the performance of the vault as an engineered barrier.... Microbial activity in the sand annulus surrounding the container may be enhanced ... Corrosion of the container may be accelerated and the performance of the vault seals may be adversely affected ... Thus, a prolonged resaturation period might accelerate the release of contaminants from the vault to the geosphere.... the thermal conductivity of the buffer and backfill would be lower and heat dissipation would be less efficient than predicted by the model. The possibility therefore exists that vault temperatures may rise above 100 C. [Comment 359, Source Document tec004, Page 049, Section 6.2.3]

The assumption that convective transport should not be a problem is not justified... the relevant estimates of Rayleigh numbers is not presented to justify the assumption. Convection in the unsaturated sand annulus and the backfill could take place in the air phase. [Comment 36, Source Document tec004, Page 122, Section B-2.1.9]

There is insufficient information on how the cement-based sealing materials will perform in unsaturated or undersaturated conditions.... The self-healing properties of cement develop when hydration products form within the fractures as water infiltrates. This process is dependent, in large part, upon establishment of fully saturated vault conditions. Little self-healing potential may exist should full saturation of buffer and backfill materials within the vault not develop, as would be the case during the preclosure and early postclosure phases. During these early phases of waste containment estimated to last for 100 years or more, when the greatest heating potential and highest vault temperature conditions will exist, the potential for cement-based material cracking will also be highest. In such periods, little credit should be taken for the healing capabilities of cement-based sealing materials. [Comment 66, Source Document tec004, Page 128, Section B-2.2.5]

Partial resaturation or non-uniform resaturation could lead to residual air; this, in combination with microbes and high temperatures could cause problems with accelerated corrosion of the container and detrimental effects on the vault seals. [Comment 141, Source Document tec004, Page 165, Section E-2.1.2]

In summary, the SRG concludes that a number of uncertainties associated with buffer and backfill resaturation have not been adequately investigated by AECL:

- corrosion may take place under conditions of partial saturation, and may be enhanced due to oxygen in the air within pore spaces;

- cracking in the buffer and backfill may develop during the presaturation period, and may persist;
- clay swelling capacity may not be fully realized;
- gaseous diffusion of 14C may be important;
- residual air may sustain microbial activity;
- heat dissipation may occur at a rate different than considered; and

- physical properties of buffer and backfill have not been adequately characterized for unsaturated and saturated conditions.

Consequently, the decision to not account for the resaturation time in the vault model is not necessarily conservative. [Comment 220, Source Document tec004, Page 203, Section F-2.1.4]

OPG RESPONSE

The level of safety analyses conducted by AECL for the 1994 EIS was considered to be adequate for the concept acceptance phase. The assumptions of early saturation in the vault are conservative since they enable a transport pathway to the geosphere for radionuclides released from any assumed failed containers in the vault.

Transient effects in the vault are mostly driven by thermal effects and the saturation process, which depends on site conditions. AECL and OPG studies on repository heating have shown that peak temperatures near the container and buffer materials occur by about 20 years after emplacement (Baumgartner and Ates 2001) and then fall slowly. Saturation of the buffer and backfill materials may take hundreds or thousands of years, depending on the hydraulic properties of the surrounding rock mass (for example, see McMurry et al. 2003).

OPG and other waste management organisations (e.g., SKB) are continuing the conduct research into understanding the transient effects in the vault and the potential impact on the performance of the engineered barrier system. Further detailed analyses for short-term transients would be conducted as part of the normal design update and site-specific evaluation and assessment process.

References:

Baumgartner, P. and Y. Ates. 2001. Packaging plant and repository factors affecting the selection of preferred used-fuel container geometries and capacities. Prepared by Atomic Energy of Canada Limited. Ontario Power Generation, Nuclear Waste Management Division Report 06819-REP-01200-10064-R00. Toronto, Ontario.

McMurry, J., D.A. Dixon, J.D. Garroni, B.M. Ikeda, S. Stroes-Gascoyne, P. Baumgartner and T.W. Melnyk. 2003. Evolution of a Canadian deep geologic repository: base scenario. Prepared by Atomic Energy of Canada Limited. Ontario Power Generation, Nuclear Waste Management Division Report 06819-REP-01200-10092-R00. Toronto, Ontario.

4.03.01.06 System Performance - Vault - General - Precipitation in the Container

PARTICIPANT COMMENTS

Atomic Energy Control Board

It is not clear why contaminant precipitation is assumed to occur in the buffer and not in the container where the concentrations should be highest (Postclosure PRD, p. 127 and p. 179). [Comment 598, Source Document gov002, Page 41, Section C.1.1(iii)]

OPG RESPONSE

The statements in the Postclosure PRD are not as precise as they should have been. In the EIS, precipitation of all nuclides (except U) is assumed to occur in the container (Johnson et al. 1994, p.144).

In the EIS, the rate of fuel dissolution is calculated using a (UO2) solubility limited dissolution model. However, in theory, the solubility of UO2 could vary from location to location due to inhomogeneities (Johnson et al. 1994, p.151). Because, in this model, precipitation of uranium downstream of the fuel/buffer interface would enhance the rate of fuel dissolution (Garisto and Garisto 1986), the possible effect of uranium precipitation in the buffer (downstream of the fuel/buffer interface) was accounted for in the EIS (Johnson et al. 1994, Section 5.5.3.2).

In the SCS (Johnson et al. 1996), a kinetic model was used to predict the rate of fuel dissolution. For such a model, precipitation of uranium outside the container would not affect the calculated rate of fuel dissolution. Consequently, neglect of nuclide precipitation outside the container, which is done in the SCS, would be conservative. It is anticipated that in future safety assessments a kinetic model would be used to predict the rate of fuel dissolution (Kolar et al. 2000).

References

Garisto, N.C and F. Garisto. 1986. The Effect of Precipitation on the Long-Term Release of Radionuclides from Used Fuel. Annals of Nuclear Energy 13, 591-596.

Johnson, L.H., D.M. LeNeveu, F. King, D.W. Shoesmith, M. Kolar, D.W. Oscarson, S. Sunder, C. Onofrei, and J.L. Crosthwaite. 1996. The disposal of Canada's nuclear fuel waste: A study of postclosure safety of in-room emplacement of used CANDU fuel in copper containers in permeable plutonic rock. Volume 2: Vault model. Atomic Energy of Canada Limited Report AECL-11494-2.

Johnson, L.H.D.M. LeNeveu, D.W. Shoesmith, D.W. Oscarson, M.N. Gray, R.J. Lemire and N.C. Garisto. 1994. The Disposal of Canada's Nuclear Fuel Waste: The Vault Model for Postclosure Assessment. Atomic Energy of Canada Limited Report AECL-10714.

Kolar, M., D.M. LeNeveu and F. King. An interim performance assessment model for used fuel. OPG Report 06819-REP-01200-10034-R00.

4.03.01.07 System Performance - Vault - General - Redox Conditions PARTICIPANT COMMENTS

Atomic Energy Control Board

AECL has not adequately considered the effects of the construction and long-term operation of the repository on the in situ hydrogeochemical environment. Since a repository would be essentially a mine, a "reference" mine water chemistry should also be considered (Vault PRD, p. 34 and Table 3-1a). A mine water may have a different composition for certain parameters than the in situ groundwater as a result of various anthropogenic factors. For example, mine waters may contain several hundred ppm nitrate (NO3) because of mine blasting. This is an oxidant that must first be reduced before other naturally occurring oxidants (Fe3+, Mn4+, SO42-) will become effective electron accepters and thereby lower EH. [Comment 631, Source Document gov002, Page 56, Section C.3.1(ii)]

The effects of the precipitation of ferric oxyhydroxide from groundwater seepage onto the walls, ceilings and floors of the disposal rooms during the operation of the repository on the postclosure redox conditions have not been assessed. This ferric iron will act as an electron accepter and hence slow down the establishment of reducing conditions. [Comment 632, Source Document gov002, Page 56, Section C.3.1(ii)]

Oxygen consumption by the titanium containers following emplacement (Vault PRD, p. 37) would likely be minor because the containers would have developed a passivation layer prior to emplacement.... Furthermore, the oxygen trapped in the pore space in the sand placed around the containers has not been considered. [Comment 633, Source Document gov002, Page 57, Section C.3.1(iii)]

Iron minerals are indicated to be present in the buffer (Vault PRD, p. 39) but it was previously stated that ... most of the iron in the buffer would be already oxidized. [Comment 634, Source Document gov002, Page 57, Section C.3.1(iii)]

Biotite in the backfill will not consume dissolved O2 if the groundwater that saturates the buffer bypasses the backfill because of fractures in the rock (Vault PRD, p.36). [Comment 635, Source Document gov002, Page 57, Section C.3.1(iii)]

The assumption that goethite or hematite would be more stable in the vault than amorphous ferric oxyhydroxides is both unsupported and non-conservative (Vault PRD, p.153-154). Therefore, the assumption that the magnetite/hematite redox boundary will buffer the redox conditions, rather than for example the magnetite/ferric oxide(am)potential, is unsupported. [Comment 637, Source Document gov002, Page 57, Section C.3.1(iv)]

both the pink and grey granites adjacent to Fracture Zone FZ2 are highly oxidized to a deep red colour by the formation of hematite (Geosphere PRD, p. 325).... this oxidation may be a recent product of the infiltration of oxidized meteoric water along the fracture zone to depths of several hundred metres into the batholith. Accordingly, it cannot be assumed that the groundwater resaturating the repository (at least for one constructed at a depth of 500 m) will be reducing. [Comment 645, Source Document gov002, Page 60, Section C.3.4(ii)]

Natural Resources Canada

Consideration should be given to the contribution to the process of secondary oxidants, such as sulphates and nitrates. If this contribution is considered to be insignificant, then data to support this should be presented. [Comment 759, Source Document ph2gov001, Page bar5]

Section 3.4.2 [of the Vault Model PR] ... assumes that pore oxygen in the backfill would be consumed by oxidation of biotite in the crushed granite within 8 years.... The validity of this assumption is questioned on the basis of geological observations of granitoid gravels in stream beds, which contain fresh biotite, despite residence times that greatly exceed 8 years.... To ensure reasonable certainty of a reducing environment in the vault we suggest that a reducing agent should be added to the backfill material. [Comment 724, Source Document ph2gov001, Page vau4]

With respect to redox conditions of the buffer material, great emphasis has been placed on the oxidation/reduction influence of iron. Other redox couples may play a significant role in some groundwaters and may be useful indicators of redox history or potential. These include total alkalinity, nitrogen compounds or ions (NH4), dissolved organic carbon and dissolved manganese. [Comment 806, Source Document ph2gov001a, Page 10, Section 2.2.3]

Biogenic gas also plays a role in redox reactions. If a redox front is established at the interface between the oxidizing environment and the reducing environment, dissolved uranium would be expected to precipitate when it contacts the reducing environment. This would led to a non-homogeneous distribution of radionuclides, making their distribution and transport difficult to model. [Comment 908, Source Document ph2gov001a, Page 10, Section 2.2.3]

OPG RESPONSE

The repository will be designed and sited such that reducing conditions in the vault will prevail, after the oxidants present at vault closure are consumed. Thus, the occurrence of oxidizing waters in the vault is highly unlikely. For example, at the Whiteshell Research Area (WRA), Gascoyne (1996) measured Eh and dissolved O2 concentrations in rapidly recharging groundwaters. He observed rapid consumption of O2 in the upper 200 m and measured O2 concentrations less the 1 ppb and redox potentials of less than 0 mV at a depth o 240 m.

Because a solubility limited dissolution model was used to calculate UO2 dissolution rates in the EIS, the predicted dissolution rates was sensitive to the Fe(II) solid/Fe(III) solid couple assumed to control the redox conditions in the vault. However, it is expected that in future assessments (see item 4.03.01.04), a kinetic fuel dissolution model would be used to predict the rate of UO2 dissolution, following the approach used in the Second Case Study (Johnson et al. 1996). In this case, the question of which Fe(II) solid/Fe(III) solid couple controls the redox conditions in the vault is only of minor importance.

It is expected that anthropogenic oxidants will have a relatively minor influence on the rate of UO2 dissolution, because the amount of oxidants formed by radiolysis of water within the container would greatly exceed the amounts available from anthropogenic sources. Nevertheless, it is acknowledged that the fate of anthropogenic oxidants present in the vault may need to be discussed in a future assessment.

At vault closure, O2 will be present in the void spaces of the buffer and backfill. The time needed for this trapped O2 to be consumed (by various reactions) is discussed in both the EIS (Johnson et al. 1994) and SCS (Johnson et al. 1996). Depending on the assumptions made in the calculations (Johnson et al. 1996, p 29), the trapped O2 is predicted to be consumed in between about 6 and several thousand years. In the EIS, consumption of O2 by organics in the sealing materials was neglected and it was assumed that most O2 would be consumed in the oxidation of Fe2+ formed by biotite dissolution. The time needed to consume the O2 in the backfill (which contains both clay and crushed granite) was estimated at 320 years at 25 C and 8 years at 80 C (based on an assumed activation energy for the biotite dissolution reaction). These results are not invalidated by the observation of granitoid granite in stream beds that contain fresh biotite.

In the EIS, no estimate was given for the time needed to consume the trapped O2 in the buffer (which contains Fe(III) minerals and minor amounts of Fe(II) minerals) but it was noted that this O2 would be gradually depleted by reaction with Fe2+ diffusing in from the backfill and surrounding rock and by

diffusion of O2 out of the buffer. For the SCS (Johnson et al 1996, p13), it was found that the O2 entrapped with the sealing materials would be mainly consumed by reaction with organic matter in the clays and corrosion of copper.

References

Gascoyne, M. 1996. Hydrogeochemical and geochemical data for the alternative assessment case study. Atomic Energy of Canada Limited Report TR-720.

Johnson, L.H., D.M. LeNeveu, F. King, D.W. Shoesmith, M. Kolar, D.W. Oscarson, S. Sunder, C. Onofrei, and J.L. Crosthwaite. 1996. The disposal of Canada's nuclear fuel waste: A study of postclosure safety of in-room emplacement of used CANDU fuel in copper containers in permeable plutonic rock. Volume 2: Vault model. Atomic Energy of Canada Limited Report AECL-11494-2.

Johnson, L.H.D.M. LeNeveu, D.W. Shoesmith, D.W. Oscarson, M.N. Gray, R.J. Lemire and N.C. Garisto. 1994. The Disposal of Canada's Nuclear Fuel Waste: The Vault Model for Postclosure Assessment. Atomic Energy of Canada Limited Report AECL-10714.

4.03.01.08 System Performance - Vault - General - Criticality PARTICIPANT COMMENTS

Atomic Energy Control Board

The EIS does not give an adequate justification of why the conditions leading to nuclear criticality are not expected to occur in a disposal vault in the Canadian Shield, and thus this scenario cannot be excluded from consideration without further analysis. In particular, additional analyses are required to show that sufficient accumulations of SNM to cause nuclear criticality from many failed containers are not expected for the range of conditions that could occur. [Comment 655, Source Document gov002, Page 64, Section C.6.2]

Campaign for Nuclear Phaseout

The EIS dismisses accidental criticality in one paragraph ... A review all literature on the subject, should be undertaken particularly in light of the research undertaken at Los Alamos Laboratories. [Comment 1785, Source Document pub027, Page 21, Section III.C]

Canadian Coalition for Ecology, Ethics and Religion

Examine the potential for criticality in the vault and publish the study and its findings. [Comment 1848, Source Document ph2pub011, Page 1]

by the time the Pu-239 has decayed the amount of U-235 in the vault will have increased. So criticality in the vault is a potential problem if the vault becomes flooded, because water is an efficient moderator. If it occurred the risks to human and environmental health and safety would increase dramatically and persist for a very long time. [Comment 1853, Source Document ph2pub021, Page 53, Section 08.2]

calculate criticality for CANDU discharge fuel in a geologic repository ... in sufficient detail to permit peer review. The possibility for criticality should be calculated for at least two other situations with respect to spend CANDU fuel: 1) where fuel composition is altered by preferential leaching and transport, including preferential deposition of dissolved plutonium [Comment 1835, Source Document phpub043, Page 25, Section 09]

Chemical Institute of Canada

For spent nuclear fuel from power reactors (PWR and CANDU), the fissile isotope concentrations have diminished to levels too low to achieve criticality, and, to further compound the problem, the spent fuel has too many fission products accumulated it its matrix.... a criticality accident is not possible in the disposal system proposed by AECL. [Comment 1131, Source Document tec005, Page 25&26, Section IV.i.B]

Citizens for Renewable Energy

Even though the Scientific Review Group (SRG) dismissed the possibility of accidental criticality occuring in the vault there is a counterargument presented from experts at the New Mexico Los Alamos National Laboratory (C.D.Bowman and F. Vennari 1994) that the plutonium in the buried waste could escape a leaking container and explode. This blast could set off a chain reaction in the depository resulting in the release of large amounts of radioactivity into groundwater and air. [Comment 1942, Source Document ph3pub124, Page 3]

Coalition pour la surveillance du nucléaire (COSUN)

The EIS dismisses the potential for criticality in the repository vault.... An EIS that does not deal in depth with this potential negative consequence, is grossly inadequate. [Comment 1269, Source Document pub011, Page 06]

Joint Committee of the Canadian Academy of Engineering and the Royal Society of Canada

the question of a critical condition occurring in the storage facility should be carefully considered and discussed fully in public to demonstrate openness and public participation. [Comment 1142, Source Document tec003, Page g2]

Northumberland Environmental Protection (Fairlie)

Perhaps most worrying is the AECB's concern over the assumption of the unlikelihood of criticality in the vault ... if additional analyses cannot exclude the possibility of criticality from further consideration, then the AECL concept of deep geological disposal is no longer tenable. [Comment 1345, Source Document ph2tec006, Page 04]

Northwatch

the EIS should discuss accidental criticality in a thorough manner; at present, the EIS dismisses accidental criticality in one sentence, with only one internal reference [Comment 1360, Source Document pub046, Page 10, Section d]

Oblate Conference of Canada

Another safety concern scientists have raised is that of criticality. We fear the EIS dismisses this concern too easily. [Comment 1622, Source Document ph3pub213, Page 2]

People Against Lepreau 2

when dealing with their proposal and the problem of underground stored radionuclides and their potential to go critical, the heat generated is virtually ignored. [Comment 1639, Source Document pub018, Page 3]

Saskatchewan Environmental Society

comment in detail on the risks of any form of explosion or implosion of nuclear waste in the vaults during the first few hundred years. [Comment 1672, Source Document pub040, Page 09, Section 15]

Saskatchewan Environmental Society (Shettel)

there is a slight possibility for criticality to occur external to the containers if the plutonium-239 from many canisters accumulates in subparallel fractures in the host rock, such as along preferential flow pathways. [Comment 1689, Source Document ph2tec038, Page 4]

United Church of Canada

The potential for criticality in the vault is a valid concern which must be more thoroughly addressed with detailed calculations that can be peer reviewed and brought to the public. [Comment 1743, Source Document phpub124, Page 3-20, Section 3]

OPG RESPONSE

It appears that some of the comments were based only on the brief statement given in the EIS Postclosure report, but it should be noted that this was a summary of a more substantive discussion given in the EIS Vault report (Johnson et al. 1994, p.264-268). This described analyses of three scenarios (flooded container with intact fuel, solution of Pu in container from dissolution, and

Nonetheless, the topic of criticality is obviously of interest. Given that the reference used fuel container design has been revised (and recognizing that the reference is still natural uranium fuel), it would be appropriate to revisit the criticality question. At that time, it would be desirable to consider other scenarios or conditions, to include more complete references to the literature, and to also note the relevance of natural analogs.

4.03.01.09 System Performance - Vault - General - Toxicity of Barrier Materials PARTICIPANT COMMENTS

Northwatch and Campaign for Nuclear Phaseout (Kreusch, Neumann, and Gruppe Ekologie)

Because of the large quantity of copper which comes into the geological formation it would be worth to consider the chemical toxicity for the choice of container material. But this impacts are not reflected by AECL (1996). [Comment 1585, Source Document ph2tec044, Page 09, Section 3]

OPG RESPONSE

The release of copper from used fuel containers in a deep geologic repository in plutonic rock due to corrosion in the repository is expected to be very small and is not expected to be transported to the surface environment in quantities that would impact on the natural environment. (See King and Kolar, 2000, The copper container corrosion model used in AECL's second case study, OPG Report 06819-REP-01200-10041-R00). Further safety analyses for radiological and non-radiological contaminants in a repository would be conducted as part of the normal evaluation of a facility.

4.03.01.10 System Performance - Vault - General - Radiation Effects

PARTICIPANT COMMENTS

Citizens Concerned About Nuclear Waste

Any container for the waste breaks down because the high radiation levels destroy the container with time. [Comment 1939, Source Document ph3pub107, Page 1]

Durham Wetlands and Watersheds

Little discussion in the EIS of the effects of long-term low level radiation after closure. [Comment 2008, Source Document pub043, Page 5]

Environment North

We don't have long enough experience to be sure ... whether copper or other containers may deteriorate or crystallize under heat and radiation, over tens of thousands of years. [Comment 2089, Source Document ph3pub106, Page 1]

Kenora Committee Against Nuclear Waste

eventually the containers will deteriorate, as our technologies cannot deal with the stresses that any alloys that are used will be subjected to. The alloys making up the containers will be subjected to radiation, ever increasing heat, internal gas pressure due to gases given off by the radioactive process, deterioration which is unpredictable and also by the external pressure from the deterioration of the rock exposed granite. [Comment 2128, Source Document ph3pub063a, Page 34]

It is not possible to develop metal alloys that would have the strength for the purpose of containing radioactive nuclear waste. Radioactivity contaminates everything it comes in contact with. There is no material that can stop the radiation from nuclear fuel waste.... The forces from the highly radioactive wastes will break down the alloyed compounds just as has been and is happening in the Candu reactors at the present time. [Comment 2130, Source Document ph3pub184, Page 1]

United Church of Canada

Even without physical leakage of the waste from containment, the radiation emanating from the buried waste will have an impact due to its ionizing nature on all surrounding matter which absorbs the radiation, including the container, the buffer, groundwater and any microbial life in that groundwater. The effects on the integrity of containment materials, groundwater chemistry, and microbial life and impacts of such changes have not been adequately addressed in the EIS [Comment 1751, Source Document phpub124, Page 3-45, Section 3]

OPG RESPONSE

The radiation levels at the container are not strong enough to directly affect the metal (McMurry et al. 2003). Radiation may affect the chemical environment around the container through radiolysis of water or air - see response to comments in Category 4.03.01.04.

Reference:

McMurry, J., D.A. Dixon, J.D. Garroni, B.M. Ikeda, S. Stroes-Gascoyne, P. Baumgartner and T.W. Melnyk. 2003. Evolution of a Canadian Deep Geologic Repository: Base Scenario. Ontario Power Generation Report 06819-REP-01200-10092-R00

4.03.02 System Performance - Vault - Waste Form

4.03.02.01 System Performance - Vault - Waste Form - Fuel Sheath

PARTICIPANT COMMENTS

Scientific Review Group

The role of the zirconium alloy sheath as a barrier is ignored... a nominal calculation of the possible rate of mechanical and corrosive failure rates of the zirconium alloy sheaths should have been performed. [Comment 30, Source Document tec004, Page 120, Section B-2.1.2]

OPG RESPONSE

The zirconium sheath surrounding the used fuel pellets is recognised as a barrier to the release of radionuclides from used fuel. It has been conservatively ignored in safety assessments because the failure mechanism is difficult to accurately quantify. Further analysis of this barrier is being considered by OPG.

4.03.02.02 System Performance - Vault - Waste Form - Inventory

PARTICIPANT COMMENTS

Concerned Citizens of Manitoba

Long term management solutions can be found only when the magnitude of the problem has been clearly defined. This definition requires that we are able to clearly identify the total amount of waste and its chemical and physical composition. [Comment 1955, Source Document phpub153, Page 3]

We agree that the amount and composition of waste from the nuclear industry is dependent on decisions regarding nuclear energy made by a variety of government and industry bodies, however we argue that these decisions must be made in advance of planning for any permanent disposal facility.... These uncertainties are unacceptable in an environmental impact statement. [Comment 1954, Source Document pub034, Page 6]

Concerned Citizens of Renfrew County

The HLW EIS lacks a detailed analysis of the current status of HLW inventories in Canada, and none of scenarios for the size of disposal facilities reflects a realistic projection of future HLW inventories. [Comment 1974, Source Document phpub171, Page 3]

Northumberland Environmental Protection (Fairlie)

Any safety assessment of the disposal of spent fuel must contain a clear description and sufficient detail of the expected spent fuel inventory. This should include tonnes of spent fuel expected to be generated under specific operating conditions (burnups), broken down by past and future years of operation of various reactors. [Comment 1338, Source Document ph2tec006, Page 03]

the source terms of the 68 main nuclides in spent fuel should be presented in tabular form ranked by size for ease of assessment in addition to table 5.4, (together with values for Cs-137 which have been unaccountably omitted). It should be explained how these are determined, and the assumptions used should be discussed. These amounts should also be presented in becquerels, as well as kilograms and moles. [Comment 1339, Source Document ph2tec006, Page 03]

Northwatch

the description of nuclear fuel waste in the EIS should include lists and descriptions of all of the radionuclides found in the waste; the description of the radionuclides should include a description of month by month changes/activity for the first year, year by year changes/activity for the first decade, decade by decade changes/activity for the first century, and century by century thereafter [Comment 1356, Source Document pub046, Page 08, Section d]

the EIS does not adequately discuss interaction among active constituents in the fuel waste [Comment 1378, Source Document pub046, Page 15, Section d]

Northwatch (Willis)

the assumption that all fuel bundles are exactly the same in terms of radioactive constituents has a significant impact on AECL's modelling. One factor that is ignored is the probability that there will be differences due to variable burnups or the use of plutonium fuel (mixed oxide' or MOX) IN Canadian reactors. Since both higher burnups and the use of MOX fuel will increase the inventory of highly radiotoxic plutonium and americium in the fuel waste, these factors need to be considered very carefully a comprehensive safety analysis. [Comment 1566, Source Document ph3pub096a, Page 08, Section 4]

OECD/NEA Review Group

The gap inventories of radionuclides (e.g., those radionuclides which are assumed to be released from the container immediately after breach) are conservatively chosen in the light of more recent Canadian and Swedish data. [Comment 1197, Source Document tec001, Page 06, Section 3.1.1]

The assumptions behind the screening out of 137Cs need to be checked. Is it conservative in all scenarios? [Comment 1231, Source Document tec001, Page 14, Section 4.3]

Scientific Review Group

The inventory of radionuclides contained in the fuel waste seems to be comprehensive and detailed ... but, there are some uncertainties about its completeness. For example, the presence of 36Cl was missed until very recently [Comment 348, Source Document tec004, Page 045, Section 6.2.2]

OPG RESPONSE

The total amount and composition of used nuclear fuel wastes in Canada has been conservatively estimated in the 1994 EIS by AECL and is considered to be bounding. The previous estimate of 10 million used fuel bundles is significantly higher than OPG's current estimate of 3.6 million bundles from current or planned nuclear power generating facilities in Canada.

The fuel age and burnup are variables that affect the radionuclide inventory in the used fuel bundles and they have been evaluated for a deep geologic repository (Tait et al. 2000).

Reference:

Tait, J.C., H. Roamn and C.A. Morrison. 2000. Characteristics and radionuclide inventories of used fuel from OPG nuclear generating stations - Volume 1 - Main Report, Volume 2 - Radionuclide inventory data. Ontario Power Generation, Nuclear Waste Management Division Report 06819-REP-01200-10029-R00. Toronto, Ontario.

4.03.02.03 System Performance - Vault - Waste Form - Dissolution PARTICIPANT COMMENTS

Atomic Energy Control Board

The fuel dissolution model does not adequately address the possibility of oxidative dissolution of the fuel from either naturally occurring oxidants in the groundwater or from anthropogenic oxidants introduced during the construction phase and operational lifetime of the repository. [Comment 603, Source Document gov002, Page 42, Section C.1.2(i)]

The maximum redox potential attainable at the fuel surface is assumed to correspond to that of the U4O9/U3O7 equilibrium boundary (Vault PRD, p.120). This assumption is non-conservative considering the uncertainty in assigning thermodynamic significance to measured potentials in the poorly poised groundwaters in the Lac du Bonnet batholith (at depths of 400-500 m) in which the actual measured potentials lie very close to the equilibrium boundary. [Comment 636, Source Document gov002, Page 57, Section C.3.1(iv)]

The solubility of Tc (which has a significant instant release fraction of about 6%) is calculated assuming that the redox conditions do not exceed the U4O9/U3O7 equilibrium boundary (Vault PRD, p. 149). Under more oxidizing conditions, there is no effective solubility limit for Tc (SKI, 1991), and AECL has not considered this scenario. The assumption that a redox front will form within the buffer is both unsupported and unlikely considering the low concentrations of reactive reduced compounds in the buffer (Postclosure PRD, p. 91). [Comment 638, Source Document gov002, Page 57, Section C.3.1(iv)]

The distribution of calculated uranium solubilities (Vault PRD, Figure 5-10, p. 141) is much lower than the measured concentrations in groundwaters of the Lac du Bonnet batholith (Gascoyne, 1989).... Furthermore, uranium solubility under highly saline conditions (such as represented by Standard Canadian Shield Brine reference groundwater) is poorly understood (Vault PRD, p. 142). Such waters can occur at depths of 1000 m, and the impacts of these waters on radionuclide solubilization (for example, by chloride complexation) are not assessed in the EIS. [Comment 643, Source Document gov002, Page 59, Section C.3.3(i)]

Canadian Coalition for Ecology, Ethics and Religion

It is unclear just how sensitive the solubility of the waste form is to the redox potential or pH in the groundwater ... The impact of radiolysis may affect the groundwater earlier than the time frame considered in the modelling ... there is no discussion of the impact of radiation on the oxidation state of the iron ion or on other chemicals important in redox couples in the containment environment. What if the ground water conditions are not as predicted? What if reducing conditions are not maintained? The surface of the waste form may not be the projected uranium oxide but a complex series of uranium tertiary structures containing fission products with multiple oxidation states and greater solubility in reducing conditions than the projected uranium oxide ... The modelling assumptions, including the small fraction of the fuel dissolving in the period of 100 years to 100,000 years for the in-room emplacement model, need verification. [Comment 1866, Source Document ph3pub160, Page 5]

Changes in the ground water chemistry, the reducing conditions or the uranium chemical complex could give different corrosion rates of the waste with higher dose rates from these two radionuclides [I-129 and CI-36] and others, in different time frames than those presented. [Comment 1870, Source Document ph3pub160, Page 7]

Canadian Geoscience Council

the AECL EIS document in some ways contains internally inconsistent geochemical conclusions--the results of the 27 year study of UO2 that indicates stability of the rods in wet storage vs. the evidence of dissolution and modification on longer time-scales in the Cigar Lake analog. [Comment 1070, Source Document tec002, Page 27, Section 4.2.1]

We are not aware of any evidence that guarantees that the groundwaters in any subsurface environment will be reducing enough not to affect the pellets if given access. [Comment 1071, Source Document tec002, Page 27, Section 4.2.1]

Chemical Institute of Canada

How sensitive is the performance of the containment or the solubility of the waste form or support matrix to Eh or pH in the ground water? i.e., what happens if the ground water conditions are not as predicted? For example, what are likely to be the products of biological action on the residual organic material in the backfill? Ammonia is one product of anaerobic decomposition as are humic acids, neither of which are mentioned in the report. To what extent will these products affect the ground water pH and materials performance? [Comment 1111, Source Document tec005, Page 05, Section I.1.8]

the work of Shoesmith and Sunder of AECL has been at the forefront of efforts to measure experimentally the rates of dissolution of uranium from UO2 under a range of pH and Eh conditions. However, I still do not believe that the Report goes far enough in tying these results to waste form conditions which will exist in 1,000 - 100,000 years when the fuel is eventually in contact with saline ground water.... there may be some value in carrying our some thermodynamic calculations of the stabilities of various actinide and lanthanide uranites in contact with anoxic ground water. [Comment 1114, Source Document tec005, Page 07, Section II.i.A]

Joint Committee of the Canadian Academy of Engineering and the Royal Society of Canada

It appears that the assumptions made in developing the models from experimental data have been conservative with respect to dissolution and release processes and that AECL's analysis is acceptable. [Comment 1157, Source Document ph2tec007, Page 05]

Natural Resources Canada

The presence of uranium, as a radioactive halo, at this level implies movement within the batholith, which should be taken into account and explained. This has implications for the movement of waste from the vault into the surrounding area and indicates a potential to travel beyond the distance indicated in the report. [Comment 748, Source Document ph2gov001, Page sit5]

Northumberland Environmental Protection (Fairlie)

Other examples of unconservative assumptions include the low solubility rates for U02 in spent fuel. The solubility limit used by AECL for uranium (the key parameter of the EIS, in many ways) is 3 to 4 orders of magnitude lower than that used by other countries in their studies. (NAGRA, 1994). [Comment 1346, Source Document ph2tec006, Page 04]

OECD/NEA Review Group

The fuel matrix dissolution times are intended to be realistic rather than conservative. By comparison with other international assessments, the realistic values chosen appear justifiable. [Comment 1198, Source Document tec001, Page 06, Section 3.1.1]

Scientific Review Group

there remains considerable uncertainty about the mobility of the radionuclides that occur as impurities in the uraninite crystal.... the fuel waste may be more mobile than expected and ... its long-term effectiveness as a barrier may be less than is claimed. [Comment 329, Source Document tec004, Page 035, Section 5.3]

Recent geochemical evidence from uranium ore deposits has brought into question the mobility of radionuclides from uraninite as a possible natural analog for the behaviour of uranium dioxide in fuel waste [Comment 350, Source Document tec004, Page 046, Section 6.2.2]

many of the assumptions made in modelling fuel dissolution are not fully justified.... Possible radionuclide release processes other than congruent dissolution have not been considered.... In summary, the uncertainties with respect to fuel waste dissolution are unspecified, and the absence of adequate experimental data does not convey confidence in AECL's predictions. The importance of these uncertainties to the overall feasibility of the multi-barrier concept is unstated. [Comment 29, Source Document tec004, Page 119, Section B-2.1.1]

natural uraninite does exchange oxygen isotopes with groundwater, without dissolution and reprecipitation, and this might influence the balance between the instant release fraction and the congruent dissolution fraction [Comment 160, Source Document tec004, Page 172, Section E-2.1.5]

OPG RESPONSE

Since the EIS was prepared, there have been several changes to the UO2 dissolution model. Notable are the following:

- development of a kinetic dissolution model rather than a UO2 solubility-limited model;
- revision of the thermodynamic data used in assessing solubility of U and other species;

According to the kinetic dissolution model, the dissolution rate is primarily dependent upon the strength of the radiation fields near the fuel surface, rather than UO2 solubility (Johnson et al. 1996, Kolar et al. 2000). These radiation fields promote UO2 dissolution by formation of oxidizing species near the fuel surface due to radiolysis of water. Hence, the oxidizing conditions at the fuel surface are controlled primarily by the fuel itself rather than by external redox conditions. Therefore, many of the questions related to the UO2 solubility limited model are no longer important for dissolution (e.g., anthropogenic oxidants, U4O9/U3O7 boundary, solubility of UO2, Eh/pH of groundwater).

Experiments and computer models are currently being funded by OPG to support use of the kinetic fuel dissolution model (e.g. Stroes-Gascoyne et al. 2002, Santos et al. 2003, Goldik et al 2003). Part of this work is funded under the joint NSERC/OPG Industrial Research Chair Program on Nuclear Fuel Disposal Chemistry, held by Dr. D. Shoesmith at the University of Western Ontario. Other countries are also following a similar kinetic dissolution model, and carrying out complementary research.

Independent of the dissolution model, element solubilities are still important in limiting the rate of release of low-solubility elements from the container (i.e., after release from UO2 fuel). These solubilities are calculated based on thermodynamic data (Tc, U, Np, Th, Pu) or assigned conservatively large values. The model does allow calculation of uranium solubilities in Standard Canadian Shield Saline Solution (Lemire and Garisto 1989), and for a range of groundwater conditions. However, since the EIS, one notable change is the adoption of an amorphous phase of UO2 as the relevant solid precipitate in the container, rather than the crystalline wasteform phase relevant for the EIS. This results in higher U solubilities in the container, consistent with that used in other countries. The effect of groundwater composition, including salinity and organics, on elemental solubilities should be reviewed as part of the database update for future assessments.

Regarding redox conditions within the container, the repository will be designed and sited such that reducing conditions in the vault will prevail, after the oxidants present at vault closure are consumed.

There is substantive geochemical evidence that groundwater conditions are reducing at relevant depths and have remained so for very long times; this would certainly be confirmed at any candidate site. Furthermore, the reference copper disposal canister is supported by a inner carbon-steel vessel. Failure of the vessel and ingress of groundwater into the vessel would cause corrosion of the carbon-steel vessel and generation of H2 gas (SKB, 1999). The presence of H2 gas would ensure that reducing conditions prevail within the container. Reducing conditions ensure that the solubilities of Tc and U are low.

With respect to nuclide release mechanisms, current models consider the two most likely processes: instant release and congruent release. Releases due to other mechanisms (isotopic exchange, recoil, etc.) are expected to be very small relative to these, especially since instant release values are normally conservatively defined to include fuel grain boundary inventories. In any event, the EIS and SCS studies showed that the highest predicted doses resulted from instant release of I-129 from the fuel, after groundwater contacted the fuel. This instant release source term and, hence, the highest predicted doses would not be strongly affected by groundwater chemistry which affects the rate of UO2 dissolution, i.e., the congruent release source term. This is borne out the by the sensitivity analyses carried out in the EIS (Goodwin et al. 1994).

The stability of fuel rods in wet storage says nothing about the stability of the fuel itself because the Zircaloy cladding prevents the fuel from contact with the water.

References

Goldik, J.S., J.J. Noel, H.W. Nesbitt and D.W. Shoesmith. 2003. Surface electrochemistry of SIMFUEL in dilute alkaline hydrogen peroxide. To appear in the Proceedings of the Canadian Nuclear Society, Toronto, 2003.

Goodwin, B.W., D.B. McConnell, T.H. Andres, W.C. Hajas, D.M. LeNeveu, T.W. Melnyk, G.R. Sherman, M.E. Stephens, J.G. Szekely, P.C. Bera, C.M. Cosgrove, K.D. Dougan, S.B. Keeling, C.I. Kitson, B.C. Kummen, S.E. Oliver, K. Witzke, L. Wojciechowski, and A.G. Wikjord. 1994. The disposal of Canada's nuclear fuel waste: Postclosure assessment of a reference system. Atomic Energy of Canada Limited Report AECL-10717.

Johnson, L.H., D.M. LeNeveu, F. King, D.W. Shoesmith, M. Kolar, D.W. Oscarson, S. Sunder, C. Onofrei, and J.L. Crosthwaite. 1996. The disposal of Canada's nuclear fuel waste: A study of postclosure safety of in-room emplacement of used CANDU fuel in copper containers in permeable plutonic rock. Volume 2: Vault model. Atomic Energy of Canada Limited Report AECL-11494-2.

Kolar, M., D.M. LeNeveu and F. King. An interim performance assessment model for used fuel. OPG Report 06819-REP-01200-10034-R00.

Lemire, R.J. and F. Garisto. 1989. The solubility of U, Np, Pu, Th and Tc in a geological disposal vault for used nuclear fuel. Atomic Energy of Canada Limited Report AECL-10009.

Santos, B.G., J.J. Noel, H.W. Nesbitt and D.W. Shoesmith. 2003. Analysis of film formation on anodically oxidized uranium dioxide. To appear in the Proceedings of the Canadian Nuclear Society, Toronto, 2003.

Stroes-Gascoyne, S., F. King and J.S. Betteridge. 2002. The effects of alpha-radiolysis on UO2 dissolution determined from electrochemical experiments with 238Pu-doped UO2. OPG Report 06819-REP-01300-10030-R00.

Swedish Nuclear Fuel and Waste Management Company (SKB). 1999. Deep repository for spent fuel. SR 97 – Post-closure safety. SKB Technical Report TR-99-06, Volumes I and II.

4.03.02.04 System Performance - Vault - Waste Form - Fatigue Failure PARTICIPANT COMMENTS

Natural Resources Canada

Although the thin walled container design will accommodate the compaction process for glass bead packing, it has not been shown that the required 15 minutes of sinusoidal vibration at 60Hz, with peak to peak acceleration of 39.3 m.s-2, will not cause fatigue failure of the irradiated bundles. [Comment 755, Source Document ph2gov001, Page bar3]

OPG RESPONSE

The current design for used fuel containers for a deep geologic repository is based on thick walled copper containers with an inner support structure and no glass bead particulate (see Maak, 1999, The selection of a corrosion-barrier primary material for used-fuel disposal containers, OPG Report 06819-REP-01200-10020-R00). Therefore, no glass bead packing would be required.

4.03.02.05 System Performance - Vault - Waste Form - Toxicity

PARTICIPANT COMMENTS

Canadian Coalition for Nuclear Responsibility (Regroupement pour la surveillance du nucléaire)

quantify the toxicity of a typical irradiated fuel bundle by specifying the amount of water needed (hypothetically) to dilute all contaminants therein to the maximum concentration currently permitted in drinking water, and to present this as a function of the "age" of the bundle [Comment 1878, Source Document pub049, Page 15]

Concerned Citizens of Renfrew County

The proponent has failed to identify and rank the radionuclides and hazardous chemicals that are present in spent nuclear fuel. [Comment 1966, Source Document pub031, Page 3]

Energy Probe (Rubin)

"toxicity - an important indicator of a waste's hazard - can be meaningfully estimated by the volume of water needed to dilute a quantity of waste material to "safe" levels.... comparison [with regulatory standards], to be meaningful and unbiased, must be based on equivalent risk, amd not on regulatory irrationality.... For the "dilution-factor' method to be as meaningful as possible, we would especially like to see the comparison based on cancer risks. [Comment 2085, Source Document ph3pub131, Page 5]

Northumberland Environmental Protection (Fairlie)

The radiotoxicities of key nuclides in spent fuel should be plotted (per tonne of fuel) in dose/time or ALI/time graphs in order indicate the time frames over which the nuclides of concern will last. This time frame should extend to at least 100,000,000 years, the time period in other assessments of radioactive waste repositories. [Comment 1340, Source Document ph2tec006, Page 03]

OPG RESPONSE

Although the decrease in potential hazard of used fuel with time can be presented in various ways, OPG finds that the simple graph of total radioactivity with time is generally sufficient. Oter safety indicators are being evaluated in the Third Case Study (Gierszewski et al., in preparation).

Reference:

Gierszewski, P.G. et al. Third Case Study postclosure safety assessment. OPG Report 06819-REP-01200-10109-R00 (in preparation). 164

4.03.03 System Performance - Vault - Container

4.03.03.01 System Performance - Vault - Container - Mechanical Failure PARTICIPANT COMMENTS

Atikokan Citizens for Nuclear Responsibility

are the new copper containers scientifically sound and will last for a million years?... I find it hard to understand how any group or individual can say what will happen that far from now.... how may ice ages will have come and gone? 10? 20? What about earth quakes? There are just too many unknowns. [Comment 1773, Source Document ph3pub076, Page 4]

Atomic Energy Control Board

AECL's claim of generally good agreement between predicted and measured deformations in the disposal container (Barriers PRD, p. 80) is not warranted. The discrepancies between simulation and observations arise from the inappropriate simplification of treating the glass bead infilling material as a solid, and hence testing, understanding and simulation of the particulate is neither complete nor adequate (Barriers PRD, p. 183). [Comment 608, Source Document gov002, Page 44, Section C.1.3(i)]

The derived failure criterion for titanium plate is not conservative. The safety factor from the ASME code is being applied to the through-wall strain instead of to the allowable tensile stress (Barriers PRD, p. 379). In doing so, AECL over-estimates the stress that titanium plate could withstand by 50%. [Comment 609, Source Document gov002, Page 44, Section C.1.3(i)]

The predicted stress load on the emplaced container is not conservative. The only loads considered are from hydrostatic pressure and uniform buffer swelling. The load prediction does not include contributions from thermal expansion of the porewater, the buffer and rock matrices and from the local in situ stresses (Barriers PRD, p. 183 and p. 219). Neither are the effects of non-uniform loading (due to non-uniform buffer resaturation and swelling and non-uniform in situ stress) on the preferred container design evaluated. [Comment 610, Source Document gov002, Page 44, Section C.1.3(i)]

All the container lifetime predictions assume failure by corrosion (Barriers PRD, p. 185), not by collapse or buckling (even of a partly corroded container). Considering the limitations of the prototype testing and the inconsistencies in the analyses, it is not clear whether the testing and analysis of the structural integrity of the container design is sufficient to rule out collapse of a partially corroded container. [Comment 611, Source Document gov002, Page 44, Section C.1.3(i)]

Chemical Institute of Canada

low temperature creep which could occur in the temperature range typical of the container wall in the first 100 years, may not be driven by the same mechanisms as at higher temperatures (~500 deg C) where most mechanical creep is studied. At lower temperatures it is more likely that stress will accumulate in grain boundaries, leading to an increased probability of intergranular fracture. Stress could be initiated at weldments or in areas where gas pressure inside the container causes distortion of the thin outer wall. [Comment 1118, Source Document tec005, Page 09, Section I.i.B]

OECD/NEA Review Group

The utilisation in the waste package of relatively large amounts of iron-based materials, such as shell supporting structures, is deemed undesirable in the EIS ... The Group considers that a final decision on whether to implement iron-based materials should consider this more fully and should be tied to the final demonstration that the Reference Case container has, indeed, the necessary mechanical stability.... In any future licensing case, it will be necessary to give a more comprehensive analysis of the container for different scenarios. [Comment 1202, Source Document tec001, Page 07, Section 3.1.2]

Saskatchewan Environmental Society

what [would] the impact of the combined pressures from swelling clay and from water pressure at a depth of 1000 m ... be on distorting or breaking copper containers. [Comment 1697, Source Document ph2tec039, Page 6]

Saskatchewan Environmental Society (Shettel)

It is also assumed that the only failure mode for copper containers is manufacturing defects in the welding process.... site specific information is required to calculate the probability that localized failure of a container might occur under specific conditions. Slippage of rock along faults and fractures may cause shearing of canisters during periods of maximum loading (glaciation). [Comment 1685, Source Document ph2tec038, Page 2]

Scientific Review Group

non-uniform pressure from partially saturated buffer, bending stress, thermal stress and creep are also likely to increase the rate of container failure. [Comment 340, Source Document tec004, Page 043, Section 6.2.1]

long-term thermo-mechanical damage-related failure mechanisms have not been adequately considered.... Locally higher stress concentrations ..., coupled with hydrogen production, may lead to container failure at much lower average stresses and strains. [Comment 341, Source Document tec004, Page 044, Section 6.2.1]

Stress changes in the surrounding rock, including stress changes due to fracturing, also could impose non-uniform stresses on the containers for which the containers are not designed. These stresses could lead to premature container failure. [Comment 356, Source Document tec004, Page 049, Section 6.2.3]

The cumulative effects of stresses on containers resulting from non-hydrostatic stresses in the rock webs between in-floor boreholes (including potential gas-generated pressures and thermo-mechanical stress effects), in addition to currently considered hydrostatic stresses and stresses from buffer swelling, are not assessed. The magnitude of the cumulative stress will be greater than the sum of anticipated hydrostatic stress and stress for buffer swelling. This creates uncertainty concerning the estimated rate of container failures. The combined effects of these stresses may induce mechanical rupture of the containers before the onset of corrosion failure. [Comment 469, Source Document tec004, Page 093, Section 7.4]

The reference container design for waste fuel disposal, consisting of a thin-walled titanium container, with single size particulate glass bead packing, does not appear to be robust. In view of the high stresses to be anticipated in the rock web between boreholes, and the difficulty in assuring complete particulate packing for internal support, it is likely that mechanical failure due to buckling of significant numbers of containers can be expected [Comment 42, Source Document tec004, Page 123, Section B-2.2.1]

no consideration is given to rock loading from stress concentration around the rock webs between the emplacement boreholes. Horizontal rock stress in the original state exceeds vertical rock stress; accordingly, there is no a priori reason to believe that the loading is hydrostatic, rather than deviatoric. The assumption of hydrostatic loading of 12 MPa forms the central theme of design and testing (R-Barriers 1994: Chapter 3), and has led to a highly non-conservative design.... Modification of the emplacement scheme or reconfiguration of the vault, for example, to allow in-room rather than in-borehole emplacement, may be required to ensure transmission of near hydrostatic (isotropic) stresses to the container system. [Comment 44, Source Document tec004, Page 124, Section B-2.2.1]

the denseness of packing should be a primary design consideration. It is not fully addressed in the document.... repeated vibration at different frequencies and durations ... cannot generate a void-free condition to maintain high internal pressure, a prerequisite for ensuring mechanical stability. It is curious that a uniform size of glass beads was chosen since it is well known that a graded assemblage of particles would produce much denser packing than a single-sized assemblage. This issue is not addressed in the document. [Comment 45, Source Document tec004, Page 124, Section B-2.2.1]

To ensure mechanical stability of the container, (safety from collapse) either the packing must be sufficiently dense or the wall thickness of the container must be considerably increased, or both. [Comment 46, Source Document tec004, Page 124, Section B-2.2.1]

As the container corrodes, there will be problems with geometric symmetries. For instance, out-of roundness that is critical in buckling calculations would become a factor. AECL has not addressed this aspect. [Comment 47, Source Document tec004, Page 124, Section B-2.2.1]

Nickel ... is virtually dismissed in R-Barriers which discusses only the properties of complex nickel alloys (R-Barriers 1994: pp.166-172), and ignores the possible use of commercially pure nickel, which has mechanical properties at least equivalent to those of copper, and, depending upon purity, to those of titanium. [Comment 486, Source Document tec004, Page 125, Section B-2.2.2]

With the influence of incremental thermo-mechanical stresses in the order of 15-16 MPa, the integrity of the present thin walled titanium waste containers as primary engineering barriers to radionuclide release is suspect. No estimates of the increased rate of container failure are presented should thermo-mechanical stresses of this magnitude actually develop. [Comment 97, Source Document tec004, Page 140, Section C-2.2.5]

Reference containers ... are planned to be capable of surviving hydrostatic loading conditions when a minimum 2 mm wall thickness exists to maintain structural integrity. However, buckling failure has been reported for at least one size-scaled titanium container which would tend to disprove such assertions. Non-hydrostatic loading would also lead to higher stress levels in the container, accelerating hydrogen-induced cracking in the corrosion processes. Non-uniform circumferential thickness loss due to corrosion could make the container more susceptible to buckling. Experimental results for non-hydrostatic loading conditions are required to demonstrate the integrity of the container design. [Comment 224, Source Document tec004, Page 206, Section F-2.1.8]

OPG RESPONSE

Copper containers for used fuel are being designed to withstand glaciation and other natural processes and are expected to last for at least 100,000 years years (see McMurry et al 2003, King and Kolar 2000).

In 1999, OPG investigated the feasibility of selecting a corrosion barrier material for used fuel containers in a deep geologic repository. In addition, OPG reviewed the reference packaging material to fill the void space inside the container. The review concluded that glass beads could not provide assurance that the container would not collapse due to anticipated hydraulic pressures in the vault. OPG investigated a number of inner support structures for the container.

In 2001, OPG replaced AECL's reference glass bead packing with a carbon steel inner vessel to provide mechanical strength to the used fuel container. This updated container design (Russell and Simmons 2003) is consistent with similar repository concepts in Sweden and Finland.

References:

King, F. and M. Kolar. 2000. The copper container corrosion model used in AECL's second case study. Ontario Power Generation Report 06819-REP-01200-10041-R00.

McMurry, J. et al. 2003. Evolution of a Canadian deep geologic repository: Base scenario. Ontario Power Generation report 06819-REP-01200-10092-R00.

Russell, S.B. and G.R. Simmons. 2003. Engineered barrier systems for a deep geologic repository in Canada. Proc. 10th International High-Level Radioactive Waste Management Conference, Las Vegas, USA.

4.03.03.02 System Performance - Vault - Container - Corrosion PARTICIPANT COMMENTS

Atomic Energy Control Board

No support is offered for the contention (Barriers PRD, p. 180) that the current information on Grade 2 titanium is sufficient to justify corrosion predictions for thousands of years but the information on corrosion of Grade 12 titanium is not. The statement that titanium corrosion is well understood (Barriers PRD, p. 242) is an overly-optimistic simplification of the current state-of-the-art of Ti corrosion science. [Comment 613, Source Document gov002, Page 45, Section C.1.3(ii)]

Because the crevice corrosion front precedes the uniform corrosion front, the statement that the depth of the localized corrosion front does not exceed the wall thickness to guarantee mechanical stability (i.e., the corrosion allowance) before the uniform corrosion front exceeds the corrosion allowance appears to be inconsistent. [Comment 616, Source Document gov002, Page 46, Section C.1.3(ii)]

The conclusion that the model assumption of aerated conditions for container corrosion predictions is conservative (Barriers PRD, p. 163) needs to be qualified. The extent to which the assumption is conservative, the extent to which the quantity of initially trapped oxygen could cause corrosion, and time period required to consume the trapped oxygen are not evaluated.... It is not clear how much oxidizable material will remain in the buffer and backfill to consume trapped oxygen once they are in place (Barriers PRD, p. 134 and Vault PRD, p. 36).... Furthermore, the extent to which the redox-controlling minerals in the vault will be oxidized during the 60 or so years of operation of the repository is not clear.... By the time of vault closure and flooding, a significant portion of the accessible redox controlling minerals could be oxidized, not only removing their capacity to consume oxidants trapped in the vault, but adding to the inventory of oxidants that need to be consumed to return to reducing conditions. [Comment 618, Source Document gov002, Page 46, Section C.1.3(iii)]

Chemical Institute of Canada

No matter how many arguments are advanced on behalf of the present day performance of titanium alloys, titanium does not possess that unusual characteristic that a nuclear waste container metal should have: an ability to use a reliable predictive model of its corrosion processes, and a proven corrosion performance track record lasting over thousands of years.... it is just not possible to predict as accurately the metallurgical and corrosion properties of titanium over thousands of years as it is with copper. For this reason we should focus on copper as the container material of choice, we should examine and correct for its potential failings and we should continue to refine predictive models of its lifetime. [Comment 1133, Source Document ph2tec026, Page 1]

Copper appears to have a distinct advantage over titanium. Titanium's corrosion resistance depends on the presence of its oxide layer: once damaged at local sites, aggressive crevice corrosion may occur rather than film reformation. This gives a completely unpredicatable propensity for corrosive failure of the vessels. In contrast, copper does not depend on an oxide layer to retard corrosion but solely on its "nobel" nature, a bulk property. Copper will require massive corrosion before rupture and time to failure is quite predictable and directly related to wall thickness. [Comment 1112, Source Document tec005, Page 05, Section I.2]

The selection of the most suitable material should be verified through sensitivity analysis addressing such issues as ... Sensitivity of container lifetime to a variety of ground water chemistry scenarios (pH and Eh). [Comment 1113, Source Document tec005, Page 06, Section I.2]

a rigorous analysis of oxygen-free copper shows that its lifetime can be predicted with NO qualifications.... By contrast, titanium owes its chemical inertness to an oxide whose porosity is a function of the alloy microstructure. Surely, the predictability of its behaviour, and that of the underlying alloy, cannot compare with the model of metallic copper. [Comment 1117, Source Document tec005, Page 09, Section I.i.B]

Environment Canada

AECL has not made a convincing case for ignoring localized corrosion such as occurs due to pitting and microbially-induced corrosion. Given the expected vault environment and the type of testing that has been performed, it is not reasonable for AECL to conclude that corrosion of the containers will not take place over a 500-year period. [Comment 837, Source Document gov003, Page 11, Section 2.3]

AECL has not taken into consideration the possible activation of copper corrosion by sulphide species likely to be present in groundwater. [Comment 838, Source Document gov003, Page 11, Section 2.3]

Corrosion science and engineering are undergoing a revolution at the present time, and AECL has made little attempt to explore newly developing techniques for extrapolating corrosion damage into the future. These techniques should at least be considered. [Comment 839, Source Document gov003, Page 11, Section 2.3]

Natural Resources Canada

The justification for selection of container materials presented in the EIS in section 4.6.3 does not differentiate adequately between mechanisms and rates for propagation of crevice corrosion and mechanisms and rates of propagation for uniform corrosion. This could lead to erroneous conclusions concerning the long term behaviour of some alloys of titanium. [Comment 705, Source Document gov005, Page 08, Section 5.12]

Published data (Schutz and Thomas 1987) of temperature-ph limits of titanium alloys in saturated NaC1 brines suggest that Grade 12 titanium may be resistant to corrosion initiation whereas Grade 2 will probably crevice corrode. [Comment 758, Source Document ph2gov001, Page bar5]

scientists of the Metals Technology Laboratory have indicated that ASTM grade 2 titanium, AECL's chosen reference material, may not be the most suitable material for spent fuel containers.... In our view, the behavior of grade 2 titanium warrants more emphasis on corrosion initiation than corrosion propagation.... Given the combination of unpredictable initiation, unpredictable propagation and a large number of containers, it is difficult to be certain that no container failure will occur.... our preliminary "worst case" analysis, showed that a 6.5mm grade 2 titanium cylinder at 150° C might be penetrated in less than ten years. [Comment 722, Source Document ph2gov001, Page vau1]

To be reasonably certain that penetration of containers made of corrosion resistant materials will not occur, it should be shown that the probability of localized corrosion incidence approaches zero over the required time frame. This might be achieved with other grades of titanium, particularly those containing traces of palladium. [Comment 723, Source Document ph2gov001, Page vau2]

we are unable to accept the estimate of barrier effectiveness developed by AECL in the background papers and summarized in the EIS. We do not reject the concept of 'long-lasting' containers in the anticipated environment. Indeed, there is a considerable body of evidence in the technical literature to support the concept. However, a more appropriate experimental approach could have been employed to estimate materials behaviour and barrier effectiveness.... We recommend one of two approaches: to investigate the probability of localized corrosion initiation of other, more resistant titanium materials (particularly those containing traces of palladium); or, to use corrosion-allowance materials, with the advantage that the behaviour of such metals as mild steel and copper over long periods is well known. [Comment 794, Source Document ph2gov001a, Page 06, Section 2.1]

Nickel Development Institute

Nickel can accommodate large additions of alloying elements making it possible to fabricate a large number of alloys that take advantage of the passive nature of nickel and the properties of the specific alloying elements. Thus, nickel-chromium-molybdenum alloys combine the good performance of nickel-chromium alloys in oxidizing media with the similarly good performance of nickel-molybdenum alloys in reducing media ... Considering conditions in a Canadian nuclear waste vault are expected to evolve from initially warm and oxidizing to eventually cool and non-oxidizing, this combination of corrosion-resistance properties is a major asset. [Comment 1444, Source Document ph3tec002, Page 1]

AECL states in their postclosure assessment documentation that "Of the alternative corrosion-resistant materials, the nickel-based alloys look promising, but only if the container is shielded to keep radiation dose rates low" ... On the basis of work performed in Germany, Smailos has shown that there is a radiation dose rate threshold below which the effects of radiation on the corrosion of C4 become negligible ... For the dual shell containers now being considered in the Canadian waste disposal program, the radiation dose rates at the surface of a container emplaced in a waste vault would be much less than this threshold value. Consequently, no deleterious corrosion effects would be expected [Comment 1445, Source Document ph3tec002, Page 2]

More recently, in work funded by NiDI with AECL, the viability of C276 as a container material was confirmed by a series of additional experiments on the susceptibility of this alloy to localized corrosion in anticipated waste vault environments. It was concluded that "The results of these tests indicate that neither of the (two) C276 specimens would be susceptible to pitting or crevice corrosion under reference waste vault conditions ... [Comment 1446, Source Document ph3tec002, Page 2]

Northumberland Environmental Protection

The AECL adopt the set of (xi) optimistic ASSUMPTIONS FOR THE COPPER CONTAINER FAILURE MODEL FOR EVOLVING REDOX CONDITIONS for the COPPER CASE 2. We conclude that the assumptions in the COPPER LONGEVITY MODEL are non-conservative and MANIPULATIVE.... But the assumption clauses in turn are carefully selected to support the premise (to increase the chance of reducing conditions) and these are not the conditions that are likely to occur in the environment. [Comment 1501, Source Document cs027, Page 1]

Northwatch and Campaign for Nuclear Phaseout (Kreusch, Neumann, and Gruppe Ekologie)

Principally pure copper is immune against stress corrosion cracking. But already a very little content of phosphor or arsen can initiate it in special environments (KAESCHE 1966). It shoud be asked for the actual phosphor contents of the copper types which will be used and the further AECL reflections to this aspect.... Furthermore copper has a certain susceptibility to stress corrosion cracking in nitrate-bearing aqueous solutions (KBS 1983, Vol. III). It should be asked whether significant nitrite concentrations in the environment of the repository are impossible ... A third problem for supporting stress corrosion cracking is the possibility of going brittle for the copper shell by neutron radiation originate by the spent fuel. In (AECL 1996, Vol. 2) no reflection of this aspect can be found. [Comment 1582, Source Document ph2tec044, Page 08, Section 3]

Northwatch and Saskatchewan Environmental Society (Richardson)

there has been NO direct comparison conducted between the performance of the copper/steel container and the original titanium container; NO in-situ tests of the in-room concept have yet been performed in the URL, and to date, ALL tests involving corrosion etc. have been performed using a 'generic' groundwater rather than a site-specific example.... Bowyer et al (Ref. 18) suggest in no uncertain terms that galvanic corrosion due to the presence of different types of metallic materials is a distinct possibility, and that the production of iron-based corrosion products could develop stresses in the containers which could lead to ruptures. In addition, Sjoblom et al (Ref. 19) pointed out that 'localised corrosion appears to be possible under reducing as well as oxidixing conditions.... Whilst accepting the assumption that 'the major argument against [stress-corrosion cracking] of the containers is that the necessary combination of stress and a suitable corrosive environment will not be present simultaneously in the vault' (p40) it would perhaps be of use to consider the effect of varying either of these supposed constants on corrosion progression. [Comment 1603, Source Document ph2tec037, Page 23, Section 4.3]

Scientific Review Group

crevice corrosion rates may be greater than those determined in short-term laboratory experiments because of the time dependence of vault re-saturation and the availability of extraneous oxidants in the non-aqueous pre-saturation environment in the vault. [Comment 336, Source Document tec004, Page 043, Section 6.2.1]

crevices tend to concentrate chloride ion ... Thus the availability and possible chemical concentration of chloride in the groundwater may also initiate or accelerate crevice corrosion to a greater degree than predicted by the model. [Comment 337, Source Document tec004, Page 043, Section 6.2.1]

The selection of a reference container material (titanium), known to be sensitive to crevice corrosion ..., and exposed to an aqueous environment that is expected to produce [this phenomenon], is questionable [Comment 51, Source Document tec004, Page 124, Section B-2.2.2]

Copper is considered to be a reasonable alternative to titanium in terms of its corrosion resistance, but little effort has been directed at designing a container fabricated from this metal (R-Barriers 1994: pp.151-164) [Comment 53, Source Document tec004, Page 125, Section B-2.2.2]

Nickel is a highly corrosion resistant metal [Comment 54, Source Document tec004, Page 125, Section B-2.2.2]

From the corrosion point of view, uncreviced titanium should be stable under oxidizing conditions, but may not be under subsequent reducing conditions, where hydrogen may be evolved. However, the passive film on titanium, while very stable to corrosion processes, can be damaged by mechanical processes such as the relative motion of the sand or buffer which is proposed to surround the container. If the passive film is damaged, the reaction rate of titanium with water has a large driving force and occurs rapidly. This reaction dissolves the metal and concurrently generates hydrogen. AECL has shown that Ca-2+ and Mg2+ will have a significant effect on crevice corrosion behaviour, leading to deep localized penetrations, and has concluded that "... the use of Grade-2 titanium cannot currently be recommended in very saline ground waters containing >15 000 mg l-1 of Ca2+ (R-Vault 1994: p.256). [Comment 223, Source Document tec004, Page 206, Section F-2.1.8]

OPG RESPONSE

In 1999, OPG investigated the feasibility of selecting a corrosion barrier material for used fuel containers in a deep geologic repository (Maak 1999). The study examined a number a candidate corrosion-barrier materials (e.g., titanium, copper, steel, nickel) and commissioned an international peer review of the report findings. The study recommended a change from AECL's reference titanium shell design to a copper shell design for the Canadian concept.
This updated container design (Russell and Simmons 2003) is consistent with similar repository concepts in Sweden and Finland.

References:

Maak, P. 1999. Selection of a corrosion-barrier primary material for used-fuel disposal containers. Ontario Power Generation Report 06819-REP-01200-10020-R00.

Russell, S.B. and G.R. Simmons. 2003. Engineered barrier systems for a deep geologic repository in Canada. Proc. 10th International High-Level Radioactive Waste Management Conference, Las Vegas, USA.

4.03.03.03 System Performance - Vault - Container - Electrolytic Corrosion PARTICIPANT COMMENTS

Atomic Energy Control Board

Galvanic coupling of the titanium to a dissimilar metal is mentioned (Vault PRD, p. 84). In particular, galvanic coupling to carbon steel which is one of the materials used for the fuel basket is discussed. However, galvanic coupling to the Zircalloy sheathing, which cannot be substituted but is an integral part of the used fuel, is not mentioned. [Comment 617, Source Document gov002, Page 46, Section C.1.3(ii)]

Saskatchewan Environmental Society

If the steel liner is deemed necessary, this begs a further question: What happens to electrolytic corrosion with bimetallic containers over one million years? [Comment 1699, Source Document ph2tec039, Page 7]

OPG RESPONSE

In 1999, OPG investigated the feasibility of selecting a corrosion barrier material for used fuel containers in a deep geologic repository (Maak 1999). The study examined a number a candidate corrosion-barrier materials (e.g., titanium, copper, steel, nickel) and commissioned an international peer review of the report findings. The study recommended a change from AECL's reference titanium shell design to a copper shell design for the Canadian concept.

This updated container design (Russell and Simmons 2003) is consistent with similar repository concepts in Sweden and Finland.

References:

Maak, P. 1999. Selection of a corrosion-barrier primary material for used-fuel disposal containers. Ontario Power Generation Report 06819-REP-01200-10020-R00.

Russell, S.B. and G.R. Simmons. 2003. Engineered barrier systems for a deep geologic repository in Canada. Proc. 10th International High-Level Radioactive Waste Management Conference, Las Vegas, USA.

4.03.03.04 System Performance - Vault - Container - Welds PARTICIPANT COMMENTS

Atomic Energy Control Board

The discussion of crevice corrosion in the closure weld (Vault PRD, p. 64) implies that a crack in the closure weld would have to be large enough to be detected by inspection to be susceptible to crevice corrosion.... Since the width of the weld is expected to be less than the width of the lid's flange, there will be a crack above the weld that could be a site for crevice corrosion. [Comment 614, Source Document gov002, Page 45, Section C.1.3(ii)]

It is not clear if there are any effects of stress on the weld's corrosion susceptibility (Vault PRD, p. 89). Scoping calculations performed by AECB staff show that the design of the lid closure might result in tensile stresses in the weld area in response to external loadings. [Comment 615, Source Document gov002, Page 46, Section C.1.3(ii)]

Campaign for Nuclear Phaseout

A review of the vault model should also include a discussion of the welds [Comment 1798, Source Document pub027, Page 25, Section III.E]

OPG RESPONSE

In 1999, OPG investigated the feasibility of selecting a corrosion barrier material for used fuel containers in a deep geologic repository (Maak 1999). The study examined a number a candidate corrosion-barrier materials (e.g., titanium, copper, steel, nickel) and commissioned an international peer review of the report findings. The study recommended a change from AECL's reference titanium shell design to a copper shell design for the Canadian concept.

This updated container design (Russell and Simmons 2003) is consistent with similar repository concepts in Sweden and Finland.

With respect to welds, a recent study by OPG on the preliminary structural analyses of used fuel containers found that the external surface of the electron-beam weld closure would be subjected to compressive stresses, which would minimise the risk of the initiation and propagation of stress-corrosion cracking of the container (Saiedfar and Maak 2002).

References:

Maak, P. 1999. Selection of a corrosion-barrier primary material for used-fuel disposal containers. Ontario Power Generation Report 06819-REP-01200-10020-R00.

Russell, S.B. and G.R. Simmons. 2003. Engineered barrier systems for a deep geologic repository in Canada. Proc. 10th International High-Level Radioactive Waste Management Conference, Las Vegas, USA.

Saiedfar, M. and P. Maak. 2002. Preliminary assessment of the deformation and stresses of copper used-fuel containers in a hypothetical deep geologic repository. Ontario Power Generation, Nuclear Waste Management Division Report 06819-REP-01300-10049-R00. Toronto, Canada.

4.03.03.05 System Performance - Vault - Container - Hydrogen-Induced Cracking

PARTICIPANT COMMENTS

Chemical Institute of Canada

there is a significant minority opinion that claims that delayed hydrogen-induced cracking of this alloy cannot be reliably predicted.... While Ikeda and others may eventually accumulate enough experimental evidence to rule out delayed cracking resulting directly from crevice corrosion, there is still the problem of hydrogen redistribution during surface treatment and in the presence of the temperature gradient from the hot waste form. Hydrogen will likely accumulate at the outer surface of the container and will be stabilised there by defects produced by mechanical work. Some crevices could produce sufficient local lateral stresses to attract this surface hydrogen to a local site where a crack could propagate. [Comment 1116, Source Document tec005, Page 08&09, Section I.i.B]

OECD/NEA Review Group

Questions were raised on the possibility of low-temperature delayed hydrogen cracking. Recent data were provided by AECL which allay this concern to some extent, although questions remain on the understanding of the initiation of this corrosion mechanism. [Comment 1200, Source Document tec001, Page 07, Section 3.1.2]

Scientific Review Group

Increased crevice corrosion will, in turn, lead to the production of atomic hydrogen in the crevices, resulting in a larger number of hydrogen-induced cracking incidents. [Comment 338, Source Document tec004, Page 043, Section 6.2.1]

compaction of the glass bead filler material during the shipping of a test container resulted in plastic buckling of the container on subsequent hydrostatic testing ... This plastic instability can be expected to increase the rate of container failure due to HIC. [Comment 339, Source Document tec004, Page 043, Section 6.2.1]

The assumption that no HIC will occur until the container temperature falls below 30°C is thus nonconservative. HIC has been reported at temperatures well in excess of 30°C.... hydrogen embrittlement of titanium alloys can occur when... Thus all of the necessary conditions would be present in the vault for the possibility of increased HIC. The observations of crack growth maxima reported at or near room temperatures, for high strength commercial alloys (R-Vault 1994: p.81) are probably not relevant to the Grade-2 alloy. In any event, these observations were obtained during short-term experiments (e.g. days). They do not document zero crack growth rates for higher temperatures, but only reductions in crack growth rates as temperature increases. The relevance of such observations to disposal for hundreds, or even thousands of years, is unknown. [Comment 343, Source Document tec004, Page 044, Section 6.2.1]

the assumption that hydrogen embrittlement of titanium or of its alloys will not be a problem at temperatures greater than 30 C is unfounded (R-Barriers 1994: pp. 178-180). [Comment 49, Source Document tec004, Page 124, Section B-2.2.1]

The selection of a reference container material (titanium), known to be sensitive to ... hydrogen embrittlement, and exposed to an aqueous environment that is expected to produce [this phenomenon], is questionable [Comment 2151, Source Document tec004, Page 124, Section B-2.2.2]

the interaction of hydrogen with titanium, under non-hydrostatic stress conditions likely to be encountered for in-borehole emplacement has not been taken into account (R-Barriers 1994: pp.178-180) [Comment 483, Source Document tec004, Page 125, Section B-2.2.2]

OPG RESPONSE

In 1999, OPG investigated the feasibility of selecting a corrosion barrier material for used fuel containers in a deep geologic repository (Maak 1999). The study examined a number a candidate corrosion-barrier materials (e.g., titanium, copper, steel, nickel) and commissioned an international peer review of the report findings. The study recommended a change from AECL's reference titanium shell design to a copper shell design for the Canadian concept.

This updated container design (Russell and Simmons 2003) is consistent with similar repository concepts in Sweden and Finland.

References:

Maak, P. 1999. Selection of a corrosion-barrier primary material for used-fuel disposal containers. Ontario Power Generation Report 06819-REP-01200-10020-R00.

Russell, S.B. and G.R. Simmons. 2003. Engineered barrier systems for a deep geologic repository in Canada. Proc. 10th International High-Level Radioactive Waste Management Conference, Las Vegas, USA.

4.03.03.06 System Performance - Vault - Container - Growth of Flaws PARTICIPANT COMMENTS

Northwatch and Campaign for Nuclear Phaseout (Kreusch, Neumann, and Gruppe Ekologie)

In AECL (1996, Vol. 2) is noted that the range of diameter of a through-wall hole in a copper shell container that could elude detection during inspection would be 0,3 to 3mm.... They don't consider the possibility for flaw growing during handling and transportation of the container. Also flaws could possibily grow as a result of unfavourable distribution of thermal stresses. For the container with the inner shell of carbon-steel is to demand a careful investigation of the influence by the corrosion of steel for the whole container defect size (see AECL 1996, Vol. 5, p. 26). [Comment 1583, Source Document ph2tec044, Page 09, Section 3]

OPG RESPONSE

OPG is conducting safety analyses to further investigate the performance of a copper container during handling and the long-term behaviour of a failed copper container with an inner steel supporting structure which would corrode. Analyses of the effect of pinhole size were conducted by AECL and have been recently conducted and documented by OPG (see Da Silva 2001). OPG's Third Case Study postclosure safety assessment of copper containers in a deep geologic repository on the Canadian Shield was initiated in 2002 and is expected to be completed in 2003.

Similar safety assessment studies are underway at SKB, Sweden, and have been discussed in their recent safety report SR97 (SKB Report TR-99-06).

References:

Da Silva, M. 2001. Scoping analyses of radionuclide isolation capabilities of container alternatives for a deep geologic repository, OPG Report 06819-REP-01300-10023-R00.

4.03.03.07 System Performance - Vault - Container - Healing of Pits and Cracks in Titanium

PARTICIPANT COMMENTS

Scientific Review Group

Members of the SRG have never seen any indication that pits or cracks in titanium could be "healed". These processes should have been omitted [Comment 152, Source Document tec004, Page 170, Section E-2.1.4]

OPG RESPONSE

In 1999, OPG investigated the feasibility of selecting a corrosion barrier material for used fuel containers in a deep geologic repository (Maak 1999). The study examined a number a candidate corrosion-barrier materials (e.g., titanium, copper, steel, nickel) and commissioned an international peer review of the report findings. The study recommended a change from AECL's reference titanium shell design to a copper shell design for the Canadian concept.

This updated container design (Russell and Simmons 2003) is consistent with similar repository concepts in Sweden and Finland.

References:

Maak, P. 1999. Selection of a corrosion-barrier primary material for used-fuel disposal containers. Ontario Power Generation Report 06819-REP-01200-10020-R00.

Russell, S.B. and G.R. Simmons. 2003. Engineered barrier systems for a deep geologic repository in Canada. Proc. 10th International High-Level Radioactive Waste Management Conference, Las Vegas, USA.

4.03.03.08 System Performance - Vault - Container - Material Performance History

PARTICIPANT COMMENTS

Northumberland Environmental Protection

what is the evidence being offered for corrosion resistance of copper. "Archaelogical artifacts ... " [and] "... native copper ..." This surely includes an over optimistic and extravagant claim. Many ore deposits of all types of metals have persisted globally. As for the artifacts, this is scarcely complete, convincing or compelling scientific evidence. The percentage of copper artifacts that have survived must be extremely small and highly dependent on specific conditions. [Comment 1332, Source Document ph2pub010b, Page 05]

Scientific Review Group

The selection of titanium as the reference material cannot be justified because there is no experimental or scientific knowledge which can demonstrate beyond a reasonable doubt that a thin-walled titanium container would survive even 300 years in potentially non-hydrostatically stressed conditions... there is evidence for the resistance of metallic copper to dissolution or corrosion from natural geological analogs. The native copper deposits of Michigan have persisted in groundwaters for in excess of a billion years ... Titanium ... use has not included exposure to conditions similar to those which would occur in the vault, nor is there any information concerning the long term performance of titanium and it's alloys, given the knowledge base of less than 50 years.... Whereas titanium and its alloys are believed to be highly resistant to MIC, the service history of titanium is relatively short, and the metal and its alloys are seldom used in situations where MIC has been a problem. [Comment 484, Source Document tec004, Page 125, Section B-2.2.2]

OPG RESPONSE

Natural analogues are not assumed to be ideal indicators of a deep geologic repository for used fuel, but merely one line of evidence in support of the case for safety of the geologic repository concept.

4.03.03.09 System Performance - Vault - Container - Initial Defects

PARTICIPANT COMMENTS

Catholic Women's League of Canada - Ontario

Also questioned is AECL's conservative projected failure rate for the proposed welded copper storage containers. [Comment 1931, Source Document ph3pub209, Page 2]

Environment Canada

the potential for failure of emplaced containers during the preclosure period requires additional study (i.e. Is the estimated failure of 1 in 5,000 containers referenced in the EIS realistic?). [Comment 850, Source Document gov003, Page 18, Section 2.8]

Northwatch and Saskatchewan Environmental Society (Richardson)

It surely cannot be claimed, yet, as the SRG appears to, that a 1 in 5000 rate for defective canisters is conclusively too pessimistic. Only time and experience will provide the answer. Werme et al (Ref. 21) demonstrated to the audience in Winnipeg that existing techniques have yet to be reliably applied to copper canister construction. [Comment 1604, Source Document ph2tec037, Page 24, Section 4.3]

Saskatchewan Environmental Society (Shettel)

On page 28 of volume 2, it is stated that Doubt (1984) claims that the range of welded copper containers with a single pin hole leak is 1 in 1,000 to 1 in 10,000. The authors of this postclosure safety analysis chose the failure rate as 1 in 5,000 containers. Of course, the more conservative assumption would be 1 in 1,000 containers (a factor of five greater), but there is no discussion to justify the less conservative number chosen. Furthermore, there is no discussion of the possibility of having more than one pin hole leak per canister; may the factor(s) that lead to a single pin hole leak cause the formation or another, or not? The presence of more than one hole in a canister obviously affects the release models, and depending on the external conditions in the buffer, backfill, and excavated disturbed zone might lead to a flow-through situation for those canisters affected. [Comment 1684, Source Document ph2tec038, Page 1]

OPG RESPONSE

In a previous study, Doubt (1984) reviewed the failure statistics for analogous nuclear sealed components. These failure data are not directly applicable to used-fuel containers because of differences in materials and processes, but the data define a range of failure probabilities for high quality vessels and piping that was judged to include that achievable for used-fuel containers. Doubt concluded that the probability of early failure of a used fuel container due to undetected fabrication defects is on the order of 2x10-4 (1 in 5000), with a range from 10-4 to 10-3.

In 2001, OPG reviewed the current literature of reported failures of analogous engineering components in order to re-evaluate the estimated probability of early container failure for the container defect scenario (Maak et al. 2001). Components considered were non-nuclear pressure vessels, nuclear pressure vessels, CANDU pressure tubes, nuclear fuel elements and nuclear piping. Overall, the data indicate that the container failure probability estimated by Doubt (1984) is still a reasonable value, although lower failure probabilities likely could be achieved. It is also similar to the value assumed by the Swedish Nuclear Fuel and Waste Management Company (1 in 4000) in their safety assessment of the canister defect scenario (SKB 1999).

References:

Maak, P., P. Gierszewski and M. Saiedfar. 2001. Early failure probability of used-fuel containers in a deep geologic repository. Ontario Power Generation, Nuclear Waste Management Division Report 06819-REP-01300-10022-R00. Toronto, Ontario.



4.03.04 System Performance - Vault - Seals

4.03.04.01 System Performance - Vault - Seals - Upper Backfill Density PARTICIPANT COMMENTS

Natural Resources Canada

A major additional concern not addressed is the behaviour of the backfill during seismic shaking. The top layer of backfill is to be emplaced by spraying as a water-lubricated slurry and over a period of time the vault will become saturated with ground water. These conditions are ideal for liquefaction.... The bentonite of the upper backfill should be tested to determine if its swelling will apply sufficient pressure to inhibit liquefaction. [Comment 789, Source Document ph2gov001, Page pos7]

Scientific Review Group

vault reference design that may lead to time-dependent crack propagation in the rock due to settling of the backfill [Comment 27, Source Document tec004, Page 116, Section B-S]

Mechanical packing of the backfill versus pneumatic packing of the backfill has not been considered. Mechanical packing of the backfill would assure some measure of quality control [Comment 37, Source Document tec004, Page 122, Section B-2.1.10]

Possible variations in the densities of the backfill layers could compromise the effectiveness of the backfill and buffer for retarding radionuclide migration. Different densities could result in different saturation rates within the backfill. For example, the uppermost lower density layer of the backfill may not saturate to the same degree as the overlying higher density buffer material. This difference in degree of saturation, coupled with overall vault instability, could lead to cracking of the upper buffer material. [Comment 508, Source Document tec004, Page 122, Section B-2.1.11]

The consequences of mechanical versus pneumatic placement of upper backfill have not been explored.... Should a significant density mismatch exist between the mechanically-placed and pneumatically-placed backfill layers, several physical reactions may arise which could compromise the effectiveness of the in-room seals as radionuclide transport barriers.... Prior to the time when full saturation of buffer and backfill materials will occur, differential swell pressures may exist within each room which can affect the integrity of the individual backfill layers... In an unsaturated condition, the upper backfill material will be unable to heal itself. [Comment 57, Source Document tec004, Page 126, Section B-2.2.3]

roof settling may arise from compaction of pneumatically placed, unsaturated, upper backfill. [Comment 67, Source Document tec004, Page 131, Section C-S]

OPG RESPONSE

OPG is considering a number of potential arrangements of engineered barriers for the in-floor borehole and in-room emplacement methods for used fuel containers. In both methods, the upper part of the emplacement room is assumed to be filled with light backfill, with a nominal mixture of 50% sodium bentonite clay and 50% crushed granite (see Baumgartner 2000). The material is assumed to be emplaced using pneumatic equipment. To date, limited testing of the emplacement method has been performed and results from these tests are expected to be published in 2003.

An alternative method of backfill placement, compaction of the backfill placed with a sloping face within a room, is being tested by SKB in the ASPO Hard Rock Laboratory. If this method is successful and can be adapted to the in -room emplacement method, it may provide an alternative to be considered in future studies.

Further work on practical emplacement methods has been planned and demonstration of the methods will occur during the siting and repository demonstration phase of the deep geologic repository program.

References:

Baumgartner, P. 2000. Elemental composition of disposal vault sealing materials, OPG Report 06819-REP-01300-10015-R00.

4.03.04.02 System Performance - Vault - Seals - Imperfections

PARTICIPANT COMMENTS

Canadian Coalition for Nuclear Responsibility (Regroupement pour la surveillance du nucléaire)

Il en va de même pour les puits et les galeries, qui ne pourront jamais être scellés parfaitement et durer des milliers d'années.

[The same goes for the shafts, tunnels and rooms, which could never be perfectly sealed for millions of years.] [Comment 1906, Source Document ph3pub192, Page 2]

Natural Resources Canada

In reading through the SRG's comments on the original EIS I had noted that the SRG was concerned that uniformly low hydraulic conditions in the buffer could not be maintained due to imperfections in the sealing materials and emplacement procedures. I think that as long as the high densities for the buffer materials can be achieved that this problem may not occur. [Comment 828, Source Document ph2gov015, Page 11]

Scientific Review Group

the buffer and backfill may not have or maintain uniformly low hydraulic conductivity, because of imperfections in sealing materials and in emplacement procedures.... transport in the buffer and backfill may not be uniformly diffusive. Allowance should have been made for some degree of imperfection in the seals. [Comment 357, Source Document tec004, Page 049, Section 6.2.3]

OPG RESPONSE

OPG has prepared preliminary design requirements for repository sealing systems. Using these requirements as the basis, OPG has initiate a program in repository seal engineering to define the issues and then develop the material properties and design tools/methods necessary to design repository effective seals that would satisfy the preliminary design requirements (Read and Chandler 2002). As part of the siting of a geological repository, the sealing systems would be demonstrated and detailed safety and performance assessments of repository seals would be conducted.

References:

Read, R.S. and N.A. Chandler. 2002. Development and integration of tools for engineering design of repository sealing systems (ENDRES) project status - March 2002. Ontario Power Generation, Nuclear Waste Management Division Report 06819-REP-01300-10051-R00. Toronto, Canada.

4.03.04.03 System Performance - Vault - Seals - Alterations

PARTICIPANT COMMENTS

Atomic Energy Control Board

Analyses of the sensitivity of radionuclide migration to deterioration of the integrity of the seals and eventual seal failure are not presented (Barriers PRD, p. 194). [Comment 2152, Source Document gov002, Page 41, Section C.1.1(iii)]

Campaign for Nuclear Phaseout

A review of the vault model should also include ... different conditions that might affect how bentonite works. [Comment 1799, Source Document pub027, Page 25, Section III.E]

What would be the consequences of reduced water flow on the bentonite layer? [Comment 1800, Source Document pub027, Page 25, Section III.E]

Canadian Coalition for Nuclear Responsibility (Regroupement pour la surveillance du nucléaire)

Deterioration of the engineering materials used to seal the shaft cannot be predicted with any certainty into the distant future. [Comment 1901, Source Document ph3pub188, Page 2]

Conservation Council of New Brunswick

Deterioration of the engineering materials used to seal the shaft cannot be predicted with any certainty into the distant future. [Comment 1989, Source Document ph3pub162, Page 2]

Environment Canada

the potential for thermally induced cracking of the buffer before resaturation needs additional consideration. Fractured buffer material could subsequently allow advective transport of the instantaneous release fraction to the backfill and could also allow potential actinide-complexing agents present in groundwater to reach the waste forms. [Comment 840, Source Document gov003, Page 12, Section 2.4]

Potential geochemical processes in the vault need to be considered with respect to the buffer and backfill. Fluids from cement-based materials (e.g. grouts), which are calcium-rich and highly alkaline, may also interact with buffer materials leading to potential dissolution of the clay matrix itself, followed by precipitation as the pH drops with water movement through the buffer. This alkaline water is not likely to be in contact with the buffer under the in-borehole emplacement option (cement-based materials are far removed from the buffer), but almost certainly will be under the in-room emplacement option (cement-based materials very close to buffer). [Comment 843, Source Document gov003, Page 13, Section 2.4]

Calcium-bearing, high-pH fluids from cement have the potential to dissolve the clay buffer matrix. This could lead to the formation of silica-lined channels or porous regions in the buffer that could seriously influence flow and transport through the vault. [Comment 846, Source Document gov003, Page 14, Section 2.5]

As the thermal pulse passes through the vault, there is likely to be redistribution of the moisture in the buffer and backfill that could, under certain circumstances, lead to local shrinkage and crack development.... If undersaturation persists, however, these cracks could remain open, enhancing various transport mechanisms. [Comment 862, Source Document gov003, Page 22, Section 2.10]

Natural Resources Canada

The information on backfill materials provides little on the nature of the buffer clay and backfill lake sediments that can be used to determine the chemical stability of these materials.... The range of materials that are likely to be supplied, or would be acceptable should be identified, and the impacts on elements of the disposal system discussed. [Comment 761, Source Document ph2gov001, Page bar6]

there is no mention of the possibility of fracturing of buffer or backfill material after placement of waste or sealing the vault. If swelling or shrinkage of the buffer and backfill occurs as a result of thermal effects and/or groundwater exclusion and intrusion, there is a possibility that this may cause formation of fractures. These fractures could become conduits for advective water movements or enhanced diffusion pathways. This phenomenon is not mentioned as an included or excluded factor and it may not have been considered. [Comment 773, Source Document ph2gov001, Page pos2]

Buffer and backfill materials are to be prepared using fresh potable water. During the thermally driven desaturation and hydraulically driven resaturation process, this water is partially replaced by much more saline groundwater from the surrounding rock. The possible effect of the change in pore-water salinity on the swelling and self-healing capacity of the buffer material should be addressed. [Comment 803, Source Document ph2gov001a, Page 09, Section 2.2.3]

the smectite in the Avonseal bentonite is believed to be Na-rich. If incoming groundwater is Ca-rich, there will be exchange with the Na-smectite and a decrease in its swelling capacity. This should be tested experimentally and should be included as a possibility in the modelling of postclosure saturation conditions. [Comment 804, Source Document ph2gov001a, Page 09, Section 2.2.3]

if the quartz-rich granite is subjected to slightly higher temperatures over time, then quartz will dissolve to some extent (this is a pH-independent process). Dissolved silica in the proposed buffer may migrate and reprecipitate along cracks, fractures and pores created during the drying of the buffer. This may serve to either block the conduits or to line these conduits and prevent re-expansion of the smectite. This scenario, including discussion of the amounts of silica that could be dissolved following closure, should be included in the modelling of the near-field. [Comment 805, Source Document ph2gov001a, Page 09, Section 2.2.3]

I feel assured now that exchange with Ca-rich waters will not pose a problem with respect to the swelling capacity and self-healing capability of these materials. [Comment 827, Source Document ph2gov015, Page 11]

I met with Dave Dixon to discuss some of my concerns about buffer materials and geochemical processes that were expressed in my original review.... Based on our discussion and reading through these references I feel that significant problems related to buffer and backfill material will not arise in the vault. [Comment 829, Source Document ph2gov015, Page 13]

Northwatch

the EIS should discuss the effect of an extended dry period on the effectiveness of bentonite as a barrier; specifically, the EIS should address the possibility of the bentonite drying and shrinking as a result of a dry period, rather that wetting and swelling; it should also discuss what would happen if the bentonite was shrunk and dried and then made wet [Comment 1365, Source Document pub046, Page 13, Section d]

Saskatchewan Environmental Society (Shettel)

unnatural temperature gradients (e.g., non-isothermal conditions) ... will lead to chemical potential gradients in the groundwater that cause the chloride to migrate away from the heat source ... changes in the brine chemistry in the buffer caused by thermal diffusivity may affect the sealing properties of the precompacted clay blocks; if the Ca/Na ratio of the resulting brine increases, then the buffer may shrink and crack allowing preferential flow pathways to the surface of the containers. [Comment 1688, Source Document ph2tec038, Page 3]

Scientific Review Group

long-term thermal and mechanical tectonic processes may compromise the effectiveness of the vault seals. AECL has recognized that the mass transport and hydromechanical properties of the seals may change over the long term (R-Vault 1994: p.17; R-Barriers 1994: p.189), but has not investigated possible consequences. [Comment 358, Source Document tec004, Page 049, Section 6.2.3]

OPG RESPONSE

Preliminary design requirements have been prepared for repository sealing systems. These requirements provide a basis for assessing the potential effects on seal performance in a repository environment. Some work done by AECL, such as the decommissioning of the Buffer/Container Experiment (see Dixon et al. 1998) has indicated that moisture is driven away from a heat source and some cracking of the buffer may occur due to localised drying. Post-test rewetting of samples of this cracked buffer material indicated that the material swelled and the cracks healed.

Recent conceptual arrangements for both in-room and in-floor borehole emplacement have assumed that compacted dense backfill material is used rather than concrete as the working floor in emplacement rooms. Therefore, there would not be any large amounts of concrete in close proximity to the buffer materials surrounding the used-fuel container (see Baumgartner and Ates 2001).

OPG is planning to conduct detailed safety and performance assessments of repository seals, and to study the properties of repository sealing systems in an environment that is representative of repository conditions (Read and Chandler 2002).

References:

Baumgartner, P. and Y. Ates. 2001. Packaging plant and repository factors affecting the selection of preferred used-fuel containers geometries and capacities. Ontario Power Generation Report, 068219-REP-01200-10064-R00.

Dixon, D.A.; Chandler, N.A.; Wan, A.W-L.; Stroes-Gascoyne, S.; Graham, J.; Oscarson, D.W. 1998. Pre- and Post-Test Properties of the Buffer, Backfill, Sand and Rock Components of the Buffer/Container Experiment. Atomic Energy of Canada Limited Report AECL-11786; COG-97-287.

Read, R.S. and N.A. Chandler. 2002. Development and integration of tools for engineering design of repository sealing systems (ENDRES) project status - March 2002. Ontario Power Generation, Nuclear Waste Management Division Report 06819-REP-01300-10051-R00. Toronto, Canada.

4.03.04.04 System Performance - Vault - Seals - Displacement

PARTICIPANT COMMENTS

Scientific Review Group

Possible mechanical displacement of the buffer and backfill resulting from container loading and rock web fracturing are not addressed adequately. [Comment 56, Source Document tec004, Page 126, Section B-2.2.3]

OPG RESPONSE

OPG is planning to conduct detailed safety and performance assessments of repository seals, including buffer and backfill, and to define requirements for these seals. The mechanical displacement of the buffer and backfill from the used fuel container is expected to be very small. For example, work for the Japanese H12 repository project has indicated a mechanical displacement of the buffer by the container of less than 5.1 mm over 10,000 years for vertical emplacement, and less than 2.6 mm for horizontal emplacement (see JNC 2000, page IV-179).

References:

JNC 2000, H12: Project to establish the scientific and technical basis for HLW disposal in Japan, JNC Report TN1410 2000-003, Supporting Report 2, Repository Design and Engineering Technology, page IV-179.

4.03.04.05 System Performance - Vault - Seals - Thermal Osmosis PARTICIPANT COMMENTS

Atomic Energy Control Board

The conclusion that thermal osmosis is insignificant compared to hydraulic conduction in compacted clays (Barriers PRD, p. 198) requires justification especially since the hydraulic conductivity of the compacted clay is so low. [Comment 601, Source Document gov002, Page 41, Section C.1.1(iii)]

OPG RESPONSE

Based on previous studies (Mitchell 1976; Mitchell 1991), the effects of thermal osmosis on water flow are generally considered to be insignificant when compared with those of hydraulic conduction, electro-osmosis and normal osmosis.

More recently, Soler (2001) studied the potential effects of coupled transport processes in clay, which include advection, chemical diffusion, thermal and chemical osmosis, hyperfiltration and thermal diffusion. The results from the modelling indicate that the coupled phenomena will only have a very minor impact on radionuclide transport in the Opalinus Clay.

OPG is continuting to conduct detailed safety and performance assessments of repository seals, including buffer and backfill, and to define requirements for these seals.

References:

Mitchell, J.K. 1976. Fundamentals of Soil Behaviour. John Wiley and Sons, Toronto.

Mitchell, J.K. 1991. Conduction phenomena: from theory to geotechnical practice. Geotechnique 41(3), pp. 299-340.

Soler, S.M. 2001. The effect of coupled transport phenomena in the Opalinus Clay and implications for radionuclide transport. Journal of Contaminant Hydrology 53, pp. 63-84.

4.03.05 System Performance - Vault - Excavation Damage Zone PARTICIPANT COMMENTS

Atomic Energy Control Board

The excavation-damaged zone (EDZ) is not considered in vault release model. A disturbed rock zone around the excavated opening could provide a route by which nuclides could bypass (by advection or diffusion) the backfill.... Exclusion of the EDZ from the vault model cannot be supported if it is hydraulically connected with fractures in the WEZ.... There seems to be no consideration of enhancement of the EDZ by the expected 10 MPa swelling pressure of the Highly Compacted Bentonite gasket in the tunnel plugs (Barriers PRD, p. 215) or in other drift and shaft seals.... It needs to be shown that the design of these seals will function as desired, and not make matters worse by fracturing the weak zones already existing in the rock. [Comment 595, Source Document gov002, Page 40, Section C.1.1(ii)]

The groundwater modelling by Chan and Stanchell (1990) ... with the upcast shaft on a height of land was used as the basis for deciding that the ... excavation damage zone did not need to be included in the GEONET network for the postclosure safety assessment (Vault PRD, p. 172 and 173). However the Postclosure PRD clearly shows that the upcast ventilation shafts are located in a discharge area in the Pinawa Channel (Figure 5-15). The surface topography map for AECL's three-dimensional groundwater flow model (see Figures 5.5.2 and 5.5.3 in the Geosphere PRD) also indicates that the upcast shafts occur in a topographic low area. As such, the ... excavation damage zone [was] excluded from the postclosure safety assessment based on a modelling assumption that contradicts the location and layout of the hypothetical vault in the Postclosure PRD. [Comment 627, Source Document gov002, Page 54, Section C.2.5]

Canadian Geoscience Council

Current technology limits the ability to assess the significance of excavation damage in the EDZ, and unless this can be done well, a comprehensive program of sealing and grouting to convert the EDZ into a true WED should be considered before there is backfilling. [Comment 1052, Source Document tec002, Page 21, Section 3.4.2]

New models should be developed that include the effects of fractures created during mining and emplacement of the repository. [Comment 1055, Source Document tec002, Page 21, Section 3.4.3]

Chemical Institute of Canada

During excavation, it is virtually impossible to avoid introducing cracks in the rock formation. It is not clear, from the summary brochure AECL-10721, COG-93-11, to what extent this will increase the problem of ground water penetration of the disposal vault, or, more importantly, facilitate the ingress and egress of water and hence transport of radioactive material. This poses the possibility that resaturation of rock with water may be very fast, and the mobility of water in and out of the disposal vault may be much greater than would be suggested by studies of the porosity of undisturbed rock. [Comment 1126, Source Document tec005, Page 23, Section IV.i.1]

Environment Canada

the AECL analyses have generally been based on (a) underestimates of the in-situ stress coupled with (b) overestimates of the rock-mass strength, leading to underestimates of the degree of cracking (and increase in permeability) which may occur with time in the rock beneath the rooms and around the emplacement boreholes.... the extent of rock fracturing will be greater than that predicted in the EIS. The effect that this has on the performance of grouts and seals, waste emplacement methods, overall disposal facility design, and radionuclide transport should be considered. [Comment 847, Source Document gov003, Page 15, Section 2.6]

AECL has failed to address ... groundwater flow through an excavation damage zone parallel to and beneath the repository rooms. [Comment 852, Source Document gov003, Page 20, Section 2.9]

there were also several issues that were not adequately addressed ... the potential for radionuclide transport through the excavation damage zone due to the inability to seal such induced fracture systems [Comment 869, Source Document gov003, Page 26, Section 2.13]

Joint Committee of the Canadian Academy of Engineering and the Royal Society of Canada

Modeling ... is necessary but does not provide a unique interpretation of "ground truth". Furthermore, the simulations do not appear to have included the effects of fracturing induced during excavation. [Comment 1149, Source Document tec003, Page w08, Section 6]

Natural Resources Canada

As borehole wall failure is anticipated, its significance should be considered.... The cracks are not likely to extend beyond half the borehole diameter (0.62 m), but as minimum borehole spacing is 0.68 m, they could link one borehole to the next. Thus a network of fractures could develop around each corridor of boreholes. [Comment 768, Source Document ph2gov001, Page eng2]

Scientific Review Group

Excavation-induced or thermally-induced fractures could provide preferential pathways for contaminant transport between vault rooms and from the vault to pre-existing or stress-induced fracture zones in the rock. AECL has not shown by thermo-geomechanical analyses that the rock surrounding the vault, which covers an area of 2 km by 2 km, will be sufficiently stable over the long term to prevent the development fractures. [Comment 354, Source Document tec004, Page 049, Section 6.2.3]

The information on stress and rock response obtained through measurements in single tunnels and a small number of rooms at the URL over one decade may be a poor basis for predicting the state of stress developed over 10,000 years in excavations of hundreds of rooms in a 2 km by 2 km area. [Comment 370, Source Document tec004, Page 055, Section 6.3.1]

The cumulative effects of multiple room excavations have not been considered for long term integrity of the waste exclusion zone, or for the vault stability. [Comment 60, Source Document tec004, Page 127, Section B-2.2.4]

No consideration of the depth of fracturing or influence of stress concentration, other than for individually modelled rooms, has been presented. Larger scale review and modelling of multiple vault room structures, and their interactive stress and displacement effects upon the overall repository, should have been initiated. [Comment 62, Source Document tec004, Page 127, Section B-2.2.4]

The depth of the excavation damage ... may therefore be several metres or more. Based upon long term observations of underground mines, it has also been suggested that the eventual depth of fracturing in the excavation damaged zone may continue to enlarge with time, because stress change is also progressive with time. It can therefore be expected that the eventual fracture zone depth, bounding the volume of rock which may eventually require grout sealing etc., could be appreciably larger than the presently estimated zone of disturbance. Long term assessment of rock fracture behaviour for modelled or scaled vault excavations should have been done. [Comment 63, Source Document tec004, Page 127, Section B-2.2.4]

The proposed vault design does not satisfy engineering stability requirements that were originally specified by AECL... Analyses which have been prepared by AECL have demonstrated that the 2-to-1 ratio cannot be maintained within the rock web between boreholes for the case of an in-floor mode of container emplacement.... the stability analyses were conducted using non-conservative stress information, taken to be the average for the Canadian Shield as a whole, and not actual URL site stress measurement data; the latter has been determined to be significantly higher than average Canadian Shield data [Comment 92, Source Document tec004, Page 139, Section C-2.2.2]

The observation that a limited depth of fracturing will exist about typical vault excavations has not been verified by experiments at URL. ... There appear to be many inconsistencies throughout the text in referring to expected depths of fracturing that exist or that could be expected to eventually develop. [Comment 93, Source Document tec004, Page 139, Section C-2.2.2]

There is no analysis of the effects of stress interactions which may develop between multiple room excavations, typically for a room-and-pillar facility which will consist of hundreds of individual rooms spaced over a 2 km by 2 km grid ... Multiple room excavations, over an area of 2 km x 2 km at depth, and over a period of construction lasting in excess of forty years, will create stress variations across the length and width of the vault grid. Superimposition of local stress fields from adjacent excavations may generate continuous rock deformation and fracturing over extended spatial and temporal limits. Stress superimposition effects could potentially induce localized stress concentrations about excavations which would increase the depth of the excavation damaged zone through fracture propagation. Overall repository stabilization may not be achieved until completion of all excavations over the 40-plus year construction period. In summary, the conclusion that long-term excavation stability of multiple excavations can be accurately modelled based upon short-term observation and modelling of single test site excavations is unwarranted [Comment 95, Source Document tec004, Page 139, Section C-2.2.3]

in order for the 50 m exclusion distance to remain intact (and to be effective as a design constraint), the Excavation Disturbed Zone (EDZ) must also remain intact. The SRG suggests that both regions of rock are not separate physical entities but can be considered to act as extensions of one another. Therefore, maintaining a sound and intact exclusion zone will require that very careful, additional structural modelling analyses of the facility be considered in the future. [Comment 143, Source Document tec004, Page 166, Section E-2.1.2]

The consequence of enhanced hydraulic conductivity arising from vault instability due to the conjunction of high horizontal stresses, and stress concentrations arising from the reference room and pillar and in-floor borehole emplacement designs is not addressed.... From experience at URL, high horizontal rock stresses with the current reference design of the vault, which uses in-floor borehole emplacement, will likely induce fracturing in the rock webs between the container emplacement holes and around the emplacement rooms. ... Thus enhanced permeability is expected at least along the walls of excavations, and specifically in the rock web between boreholes, allowing for enhanced advective flow and transport both vertically and horizontally around emplacement rooms and access drifts. These observations on high horizontal stress, and excavation-induced fracturing, questions both the layered representation of the disposal vault and the a priori assumption that transport in the vault occurs exclusively by diffusion. [Comment 213, Source Document tec004, Page 198, Section F-2.1.2]

The new information presented by AECL has provided adequate evidence that a vault with long-term mechanical stability and integrity can be designed and constructed, even under relatively high in situ differential stress. [Comment 899, Source Document tec004a, Page 09, Section 2.3]

The proposal to design a torus-shaped seal in the excavation-damaged zone of tunnel walls is an innovative and potentially effective solution to the problem of possible contaminant transport along the vault axis in the excavation-damaged zone (Martin et al. 1996). This would inhibit any advective transport along the excavation-damaged zone in the tunnel walls. [Comment 901, Source Document tec004a, Page 10, Section 2.4]

OPG RESPONSE

The excavation-damaged zone (EDZ) was considered in the vault release model for the Second Case Study (see Wikjord et al. 1996) and in the Third Case Study (Gierszewski et al., in preparation).

AECL and OPG agree that the in-floor borehole emplacement arrangement used in the EIS case study did not satisfy the specific stability criteria stated in R-Facility (see Simmons and Baumgartner 1994) because the rooms and boreholes were not stable in the average stresses of the Canadian Shield. During the hearings, AECL presented an alternative in-room emplacement arrangement, using ellipsoid rooms, that was shown by analysis to be stable in the high horizontal stress conditions (see Baumgartner et al. 1996). Subsequently, AECL successfully designed, constructed and assessed several large openings in the high horizontal stress environment at the URL and showed that stable opening could be excavated by selecting the correct cross sectional shape (see Read et al. 1997a). AECL also investigated the affect of temperature on the stability of openings in the high horizontal stress environment (see Read et al. 1997b).

To further quantify the excavation damage around rooms at the URL, AECL reviewed the excavation damage studies that have been undertaken at the URL (see Martino 2000). This is considered to be a key aspect of repository design and a program to develop design tools for stable underground openings in highly stressed sparsely fractured rock is now being completed (see Chandler and Read 2000).

The understanding and design tools developed in the rock stability studies are being applied in the repository sealing systems engineering program (Read and Chandler 2002).

References:

Baumgartner, P., D.M. Bilinsky, Y. Ates, R.S. Read, J.L. Crosthwaite and D.A. Dixon. 1996. Engineering for a disposal facility using the in-room emplacement method. Atomic Energy of Canada Limited Report AECL-11595, COG-96-223.

Chandler, N.A. and R.S. Read. 2000. Thermal-mechanical stability studies: Project status - March 2000. Ontario Power Generation Report 06819-REP-01200-10030-R00.

Gierszewski, P.G. et al. Third Case Study postclosure safety assessment. OPG Report 06819-REP-01200-10109-R00 (in preparation).

Martino, J.B. 2000. A review of excavation damage studies at the Underground Research Laboratory and the results of the excavation damage zone study in the Tunnel Sealing Experiment. Ontario Power Generation Report 06819-REP-01200-10018-R00.

Read, R.S. and N. A. Chandler. 2002. An approach to excavation design for a nuclear fuel waste repository - the thermal mechanical stability study final report. Ontario Power Generation, Nuclear Waste Management Division Report 06189-REP-01200-10086-R01. Toronto, Canada.

Read, R.S., J.B. Martino, E.J. Dzik and N.A. Chandler. 1997a. Excavation Stability Study - Analysis and interpretation of results. Ontario Hydro Report 06819-REP-01200-0028-R00.

Read, R.S., J.B. Martino, E.J. Dzik, S. Oliver, S. Falls and R.P. Young. 1997b. Analysis and interpretation of AECL's Heated Failure Tests. Ontario Hydro Report 06819-REP-01200-0070-R00.

Simmons, G.R. and P. Baumgartner. 1994. Disposal of Canada's nuclear fuel waste: Engineering for a disposal facility. Atomic Energy of Canada Limited Report AECL 10715, COG-93-05.

Wikjord, A.G., P. Baumgartner, L.H. Johnson, F.W. Stanchell, R. Zach and B.W. Goodwin. 1996. The disposal of Canada's nuclear fuel waste: A study of postclosure safety on in-room emplacement of used CANDU fuel in copper containers in permeable plutonic rock - Volume 1: Summary. Atomic Energy of Canada Limited Report AECL-11494-1, COG-95-552-1

4.03.06 System Performance - Vault - Borehole Stability

PARTICIPANT COMMENTS

Natural Resources Canada

The past accuracy of the Hoek and Brown failure criteria in granitic rocks is not discussed.... As different failure criteria can give either overly pessimistic or reasonably accurate predictions of borehole wall failure, it is important to know if the most appropriate failure criteria have been used. [Comment 764, Source Document ph2gov001, Page eng1]

Time dependency of failure does not seem to have been considered by the authors. Stress-induced breakouts do not form immediately, and it is known from both oil exploration and mining experience that shear fracturing and spalling can be limited by casing a hole soon after drilling. If backfill packing occurs soon after drilling, this is likely to suppress much of the failure of the borehole walls and the propagation of fractures into adjacent country rock. [Comment 765, Source Document ph2gov001, Page eng2]

Stress values used in the model are high, reflecting values measured at the Underground Research Laboratory (URL). There is insufficient data available to say whether these values are typical of the Canadian Shield. [Comment 766, Source Document ph2gov001, Page eng2]

The report does not integrate Tsui and Tsai's results with observations of borehole wall failure at the 420 m level at the URL.... It would be interesting to know if failure in these boreholes occurred as soon as drilling was completed or at a later date. [Comment 767, Source Document ph2gov001, Page eng2]

To minimize crack propagation, two alternative approaches are recommended. First, a larger separation of the holes and thus less likelihood of stress interaction would be possible if the three holes were not in a line orthogonal to the long axis of the room. We recommend that separations be increased by staggering the holes with little loss in vault capacity. Second, "Stop Zones" could be included whereby a line of holes is missed every so often to stop cracks propagating along the length of the vault rooms. [Comment 802, Source Document ph2gov001a, Page 08, Section 2.2.2]

OPG RESPONSE

AECL, and more recently OPG, have initiated studies into rock mass stability (see Chandler and Read 2000, Thermal-mechanical stability studies project status - March 2000, OPG Report 06819-REP-01200-10030-R00; Read, R.S., J.B. Martino, E.J. Dzik and N.A. Chandler. 1997. Excavation stability study - analysis and interpretation of results. Ontario Hydro Report 06819-REP-01200-10028-R00; Read, R.S, J.B. Martino, J.B., E.J. Dzik, S. Oliver, S. Falls, S. and R.P. Young, 1997. Analysis and interpretation of AECL's Heated Failure Tests. Ontario Hydro Report, 06819-REP-01200-070-R00.). In addition to these activities, the URL excavations on the 240 Level (moderate in situ stress environment) have been stable for 15 years and the 420 Level (high horizontal in situ stress environment) for up to 10 years at ambient temperature and with normal underground excavation maintenance.

One outcome of these studies has been the application of the Particle Flow Code for simulating the failure processes in Lac du Bonnet granite (see Potyondy, D. and P. Cundall. 2001. The PFC model for rock: Predicting rock-mass damage at the Underground Research Laboratory. Ontario Power Generation Report 06819-REP-01200-10061-R00; R.P Young, D.S. Collins, J. Hazzard, W.S. Pettitt and C. Baker. 2001. Use of acoustic emission and velocity methods for validation of micromechanical models at the URL. Ontario Power Generation Report 06819-REP-01200-10060-R00). The PFC does simulate many of the processes involved in the failure of the rock at the URL and offers promise for application at possible a future repository site. Using the PFC calibrated to tests conducted at site would aid in establishing the failure envelope for the rock mass at the site. Other tools, such as numerical and analytical codes (see Mitaim, S. and E. Detournay. 2001. A

damage model for brittle materials. Ontario Power Generation Report 068129-REP-01200-10063-R00), complement the use of the PFC in simulating the instabilities in rock.

The need for further work in modelling thermoporoelastic effects is being considered (see Simmons 2000, Plan for used fuel disposal technology program engineering, OPG Report 06819-REP-01200-10042-R00).

4.03.07 System Performance - Vault - Container Emplacement PARTICIPANT COMMENTS

Canadian Geotechnical Society

the in-room emplacement method may have a number of advantages over the in-borehole emplacement technique. Although there are some disadvantages of the in-room emplacement method, such as requiring a larger cavern and more buffer material, the in-room placement techniques avoids the problems of high local stress concentrations in the rock between boreholes, which could lead to rock failure across the emplacement boreholes and possible damage to the canisters ... The relative advantages and disadvantages of these two emplacement options should continue to be assessed during future studies. [Comment 1105, Source Document pub020, Page 14]

there were a number of advantages of using the in-room emplacement technique over the in-borehole emplacement method, in that the in-room placement technique avoids the possibility of local rock failure in the vicinity of the canisters while they are positioned within the boreholes, which could have a detrimental effect on their integrity. [Comment 1087, Source Document pub020, Page iv]

Environment Canada

if a significant excavation damage zone develops around the vault with the in-borehole emplacement method, there is a potential for radionuclide releases to bypass the backfill and migrate directly to the geosphere. If the backfill is bypassed, then the containment of {129}I will be adversely affected. [Comment 842, Source Document gov003, Page 13, Section 2.4]

Rock damage may be reduced, and the certainty that the backfill will act as an engineered barrier can be increased by using in-room rather than in-borehole waste emplacement. [Comment 848, Source Document gov003, Page 16, Section 2.7]

The in-borehole waste emplacement method is likely to result in the creation of a substantial excavation damage zone in the rock around the repository, particularly beneath the floors of the rooms and around the container holes.... leading to a significant uncertainty in the containment performance of the repository. [Comment 849, Source Document gov003, Page 17, Section 2.7]

Other issues identified as being of concern were: ... lack of consideration of the hydrogeological conditions under which the backfill may be bypassed by radionuclides migrating from the vault through an excavation damage zone [Comment 873, Source Document gov003, Page 27, Section 2.13]

Joint Committee of the Canadian Academy of Engineering and the Royal Society of Canada

The alternatives in vault design and construction practices, notably those incorporated into the Second Case Study, give confidence that a safe and effective design approach has been conceived and that it will be adaptable to the local conditions of a specific site. The SRG and TAC reach similar conclusions. [Comment 1183, Source Document ph3tec001, Page 4]

The continued research on suitable materials for buffering, backfilling and sealing the containers in the vault has shown them to be an effective retardant of any waste that may leak from a breached container. We agree with TAC and SRG that the in-room design, with, by comparison with other options, a substantially greater volume of buffer material enclosing the contariners from all sides, is an important demonstration of the efficacy of the engineered barriers. [Comment 1184, Source Document ph3tec001, Page 4]

Natural Resources Canada

floor emplacement will alter the stress regime and increase the chance of intersecting "flaws" in the rock mass. The correct choice of sealants might inhibit the diffusion process better if the containers are placed in excavated rooms and backfilled. [Comment 808, Source Document ph2gov001a, Page 10, Section 2.2.3]

Based on my understanding of the processes involved, I recommend that engineered barriers (buffer and backfill layers) be arranged concentrically within the vault room so as to ensure that no advective radionuclide flux can develop due to groundwater flowing in from the surrounding geosphere. [Comment 823, Source Document ph2gov015, Page 06]

Northwatch

the EIS's comparative discussion on the feasibility of the different vault systems omits the analysis which would reveal possible short term or long term consequences and environmental impact; [Comment 1367, Source Document pub046, Page 13, Section d]

Science for Peace (Energy Working Group)

A gravitational collapse of the cavities may add additional problems, particularly in a horizontal inroom emplacement of the containers. For this reason the horizontal in-room emplacement concept ... should therefore be abandoned in favour of vertical in-borehole emplacement which is less vulnerable in case of gravitational collapse of a fractured chamber. [Comment 1720, Source Document ph2pub034, Page 6]

Scientific Review Group

AECL has recognized that rock webs between boreholes may be fractured as a result of excavation damage (R-Vault 1994: p.16f), and that cracks can form near the excavation, forming new pathways (R-Geosphere 1994: p.28; R-Barriers 1994: p.189). If any such shortcut pathways were to exist, the backfill could be bypassed [Comment 364, Source Document tec004, Page 050, Section 6.2.3]

Minimal assessment of the relative advantages or demerits of in-room waste emplacement versus inborehole emplacement has been performed... Inadequate arguments have been put forward to discount the alternative in-room emplacement design.... Actual site measurements, specifically stress parametric data, reinforce the advantages of in-room placement over that of in-floor placement ... substantial rock web fracturing may result between boreholes and about the room walls for the in-floor scenario ... for the case of in-borehole emplacement, the backfill would be short-circuited as an engineered barrier in the event of buffer failure stemming either from container loading, heterogeneous resaturation or the predicted high differential stresses in the rock webs between container boreholes. [Comment 98, Source Document tec004, Page 140, Section C-2.2.6]

Thickness of backfill is not treated adequately.... The thickness of the backfill plays an important role in the vault model and must therefore either be realistic or be treated conservatively.... the backfill ... may be bypassed entirely in the in-floor borehole emplacement design. [Comment 215, Source Document tec004, Page 199, Section F-2.1.3]

AECL has studied in detail the container emplacement design (Baumgartner et al. 1996) in which the containers are placed horizontally end to end within an excavated room rather than in holes drilled in the floors of the rooms. This improved design makes the buffer and the backfill more effective. It provides for a thicker shell of buffer around the containers and it ensures that groundwater moving to and from the containers must pass through the buffer and the backfill. The use of precompacted buffer in the disposal rooms and to seal tunnels also is a significant design improvement. [Comment 900, Source Document tec004a, Page 10, Section 2.4]

OPG RESPONSE

OPG has set minimum requirements for vault sealing materials. OPG has continued to evaluate the in-room and in-floor borehole emplacement methods for used fuel containers from the perspective of design robustness, engineering feasibility, monitoring, retrievability, repository size, public safety, occupational safety, siting constraints and cost (e.g., see Maak and Simmons 2001).

At the present time, both emplacement methods appear to be viable and the selection of a preferred method will be based on underground conditions at a potential repository site and on additional engineering design studies (Russell and Simmons 2003).

References:

Maak, P. and G.R. Simmons. 2001. Summary report: A screening study of used-fuel container geometric designs and emplacement methods for a deep geologic repository. Ontario Power Generation Report 068219-REP-01200-10065-R00.

Russell, S.B. and G.R. Simmons. 2003. Engineered barrier systems for a deep geologic repository in Canada. Proc. 10th International High-Level Radioactive Waste Management Conference, Las Vegas, USA.

4 System Performance - Geosphere

4.04

4.04.01 System Performance - Geosphere - Channelling PARTICIPANT COMMENTS

Scientific Review Group

The model does not adequately account for heterogeneity and channelling of groundwater flow within the fracture zones and layers, either directly or indirectly ... The basic structure of the hydrologic model was not varied for different runs of the model; and spatial variability within the layers and fracture zones was not considered adequately. Longitudinal permeability in fracture zones was set equal to 1 x 10-13 m2; but calibration against observations from the URL drawdown experiment (R-Geosphere 1994: p.111f) "... indicated that the values were spatially variable, ranging from about 1 x 10-12 m2 to 1 x 10-17 m2, and often formed channel-like patterns in the fracture zones." Channelling, which is not built into the models, could adversely affect the performance of the disposal system by decreasing travel time and reducing the surface area available for sorption. Though only reported for the fracture zones, channelling should also be expected to occur in transport through the surrounding rocks. The assumption that the permeabilities of moderately fractured and sparsely fractured rocks are horizontally uniform (R-Geosphere 1994: Appendix D, p.361), is counter intuitive to field observations, and contrary to measurements of flow rates in URL fracture zones [Comment 241, Source Document tec004, Page 218, Section G-3.2.2]

OPG RESPONSE

The channeling effect associated with flow and transport in fractured rock can occur at three levels (Tsang and Moreno, 2001). At the single fracture level, variations in fracture aperture and in the associated permeability can occur over several orders of magnitude. At a distance level of a few fracture spacings, the mean permeability can also vary from fracture to fracture. At larger distance scales, fracture densities may also vary both within and between lithologic units. Under an imposed pressure gradient, groundwater flow will be focused into the paths of least resistance, giving rise to the channeling effect. Incorporating the phenomenon of flow channeling can help to improve the interpretation of in-situ tracer tests and the subsequent characterization of the flow system domain as a precursor to performance assessment.

The Deep Geologic Repository Technology Program is presently undertaking research of mass transport in fractured crystalline rock at the fracture (1m) and fracture network (50m) scale. These projects include the Quarried Block Experiment and the Moderately Fractured Rock experiment, both conducted at the Underground Research Laboratory. A key objective of this research is to test alternative conceptualisations of mass transport within fractures and fracture systems. The research will be conducted in a co-operative forum, in which research teams will apply equivalent porous medium, dual-continuum, discrete fracture and hybrid mathematical models to reveal characteristic fracture properties and geometry most effecting mass transport. A part of this research effort will be focused on improved fracture characterisation and conceptualisation. This will include the incorporation of revised hydraulic testing methods to quantify uncertainty and better enable characterisation of permeability anisotropy and heterogeneity in fractured rock. Both experiments are scheduled for completion in 2003.

Another aspect of this issue is realisation or geosynthesis of field derived permeability estimates within numerical models to predict groundwater flow and mass transport. A current approach being tested in the DGRTP is the application of the dual continuum code FRAC3DVS (HYDROSPHERE) with imbedded geostatistical realisations of site specific Discrete Fracture Networks (DFN) and spatially correlated permeability fields (i.e. fracture and matrix continuums). A description of the modelling strategy, for application to variably dense groundwater flow simulations, is presented by Sykes et al. (2002). The application of geostatistics in deriving DFN and permeability fields that honour field data are described in details by Chan et. Al. (2001) and Srivastava (2002ab). The application of such techniques provides a reasoned basis for assigning heterogeneous, anisotropic and spatially correlated permeability fields in numerical realisation of flow in fractured-porous media typical of the Canadian

Shield (i.e. enable improved traceability/coincidence with field observation, treatment of flow domain dimensionality and the ability to perform uncertainty analyses to illustrate robustness in flow system predictions).

References

Tsang, C.F. and Moreno, L., Flow Channeling in Fractured Rocks and Tracer Breakthrough Analysis. Fractured Rock 2001, Toronto, Ontario, March 26-28, 2001.

Chan, T., F.W. Stanchell, R.M. Srivastava and N.W. Scheier. 2001. Stochastic conditional flow and transport simulations of tracer test no. 2 (TT2) of the moderately fractured rock experiment at the underground research laboratory: a geostatistics case study. Ontario Power Generation, Nuclear Waste Management Division Report 06819-REP-01200-10039-R00.

Srivastava, R.M., 2002a, Probabilistic Discrete Fracture Network Models for the Whiteshell Research Area, Ontario Power Generation Report No. 06819-REP-01200-10071-R00.

Srivastava, R.M., 2002b, The Discrete Fracture Network Model in the Local Scale Flow system for the Third Case Study, Ontario Power Generation Report No. 06819-REP-01300-10061-R00.

4.04.02 System Performance - Geosphere - High Groundwater Pressure PARTICIPANT COMMENTS

Scientific Review Group

In the low permeability rocks " ... the pressures which are recorded are often unusually high. We are confident that most of the anomalous groundwater pressures reflect the actual in situ pressure" (R-Siting 1994: p.162). Such anomalous pressures evidently have not been included as part of the variability and uncertainty in the geosphere model in R-Geosphere. [Comment 11, Source Document tec004, Page 107, Section A-2.1.4]

OPG RESPONSE

Geosphere Performance Assessment at a candidate repository site should be based on a conceptual model that will ultimately depend on site specific physical and chemical hydrogeologic conditions. Hydrogeologic features may include the existence of anomalously elevated or depressed hydraulic heads. If these anomalous head conditions are shown to be representative of the site specific conditions (i.e. bedrock lithology, fracture geometry, permeabilities, storativities, salinity, topography) and/or long-term flow system boundary conditions (i.e. climate change, glacial cycles) they may provide useful insight of long-term flow system dynamics and physical flow system properties. An example, would be the dissipation of residual hydraulic head induced by glaciation within large domains of sparsely fracture granitic rock (Chan et al. 1998). Observation of such anomalous head conditions at repository horizons may imply flow system stability (i.e. hydraulic gradients) and suggest a certain rate of response to boundary condition perturbations. This information would benefit future performance assessment model validation and improve the understanding of flow system dynamics relative to repository time scales. Further work related to understanding the significance anomalous hydraulic heads relative to permebility distributions and long-term boundary conditions is being persued through the Regional Groundwater Flow System Analysis Program (Sykes et al. 2002) and DECOVALEX III (Chan and Stanchell, 2003). These work program are examining the relationship of permeability distributions and transient hydraulic/mechanical boundary conditions to hydraulic head distirbutions and evolution in stylised and more detailed Shield settings.

References

Chan, T., P.A. O'Connor and F.W. Stanchell. 1998. Finite-element modeling of effects of past and future glaciation on the host rock of a used nuclear fuel waste vault. Ontario Hydro Nuclear Waste Management Division Report No: 06819-REP-01200-0020 R00. Atomic Energy of Canada Limited for Ontario Hydro, January 1998.

Chan, T. and F.W. Stanchell, 2003, DECOVALEX III, BMT3 Glaciation Bench Mark Test, Phase I, Progress Report, Ontario Power Generation Report No. 06819-REP--1300-10060-R00.

4.04.03 System Performance - Geosphere - Salinity

PARTICIPANT COMMENTS

Scientific Review Group

The list of factors that were dismissed from further analysis includes salinity ... gradients. Density gradients due to salinity are usually important in the presence of densities comparable to that of seawater. [Comment 149, Source Document tec004, Page 170, Section E-2.1.4]

At the local scale of the WRA the document does not provide the necessary geoscience data to justify... the initial conditions in the host rock: for example, the salinity of the groundwater varies with depth; also the salinity of the pore water in the rock matrix differs from that in the fractures (e.g. R-Siting 1994: Figure 6-13, p.142). These salinity variations involve density variations that may affect the flow system significantly. [Comment 492, Source Document tec004, Page 218, Section G-3.2.1]

OPG RESPONSE

It is recognized that variable groundwater salinities/densities with depth play a significant role in governing groundwater flowpaths and residence times. The higher density of saline groundwater can help to counteract hydraulic gradients imposed by regional topographically driven recharge-discharge flow systems, which may result in stagnant groundwater flow at repository horizons. Incorporation of representative groundwater salinities will be an important aspect of developing future site-specific performance assessment models. This activity has been undertaken in the Regional Flow System Analyses which is exploring the application of new and innovative 3-dimensional numerical codes for simulation of flow and transport at evolving time and space scales relevant to repository safety. A description of the Regional Groundwater Flow System Analysis program is provided by Gierszewski et al, 2001 and Sykes et al (2002).

References

Gierszewski, P., S.B. Russell, F. Garisto, M.R. Jensen, T.F. Kempe, P. Maak and G.R. Simmons. 2001. Deep geologic repository technology program - annual report 2000. Ontario Power Generation, Nuclear Waste Management Division Report 06819-REP-01200-10055-R00. Toronto, Ontario.

4.04.04 System Performance - Geosphere - Vault Location

PARTICIPANT COMMENTS

Joint Committee of the Canadian Academy of Engineering and the Royal Society of Canada

Our opinion in favour of locating deep disposal sites in regional recharge areas has been strengthened by the results of new studies. [Comment 1186, Source Document ph3tec001, Page 5]

I could find no discussion of the relative merits of recharge and discharge areas for site location [Comment 1146, Source Document tec003, Page w05, Section 5.1]

Scientific Review Group

The location of the reference case vault close to a discharge zone would appear to be at variance with the intention expressed by AECL elsewhere (EIS 1994: p.271f; R-Siting 1994: p.53), namely that the vault should be located in such a way that the distance contaminants would travel, and the travel time, be maximized. Such a location could be a groundwater recharge zone. [Comment 374, Source Document tec004, Page 055, Section 6.3.1]

An important range of scenarios that has been omitted by AECL concerns the effect on the migration paths and contaminant travel times due to placing the repository within the various parts of the regional groundwater flow system. [Comment 388, Source Document tec004, Page 058, Section 6.3.2]

The length of contaminant migration paths and travel times could also have been maximized by placement of the vault in a zone containing old (older than 100,000 years) saline water....Saline water, which is denser than the overlying younger non-saline water, will tend to remain at depth, and thus could effectively impede the transport of contaminants to the surface environment.... Container corrosion is likely to be self-limiting in the low-velocity groundwater of the saline zone because of saturation of the water with corrosion products in the vicinity of the container. [Comment 391, Source Document tec004, Page 058, Section 6.3.2]

The effects of depth, density, salinity, and regional hydraulic gradients on groundwater flow are not analyzed in the model... These three factors are independent of the rock characteristics, and are therefore less subject to uncertainty than the long-term integrity of the waste exclusion zone. Each of these three factors, or a combination thereof, could act as an important safety mechanism in controlling radionuclide release to the biosphere. [Comment 242, Source Document tec004, Page 218, Section G-3.2.3]

Isotopic analyses of groundwaters at the URL (R-Geosphere 1994: p.320), which provide convincing evidence for old groundwater regimes below depths of about 400 m, have important implications for groundwater flow rates and path lengths. Deep burial in the old groundwater regime might provide very long travel times from vault to the surface. The document does not adequately discuss the nature of this information and its significance for the design of a deep disposal facility. [Comment 2157, Source Document tec004, Page 219, Section G-3.2.6]

OPG RESPONSE

The location for a candidate repository site will likely be the result of an evaluation of an extensive selection criteria matrix. One of these criteria must be demonstrated long-term flow system stability, both hydrogeologically and geochemically. Hydrogeologic stability implies predictable, steady and long travel times which are conditions likely to be encountered along deep-seated regional ground water flow paths. Geochemical stability implies that groundwater characteristics such as redox potential, ionic strength and major/minor ion chemistry remain largely unchanged over the time periods of interest in performance assessment (10's - 100's of thousands of years). The hydrogeologic and geochemical conditions that are indicative of long-term flow system stability also tend to coincide with increased ground water salinity and density. These characteristics are beneficial for repository

performance assessment since they tend to mask the hydraulic gradients imposed by a topographydriven regional flow system and promote long ground water residence times.

Recently, the hydrogeochemistry of the Lac du Bonnet granitic batholith located in the Whiteshell Research Area (southeastern Manitoba) has been reviewed (Gascoyne, 2000). This review has confirmed that the upper ~200 m of bedrock contains active groundwater circulation within the fracture network as indicated by low salinity, Ca-Na-HCO3 groundwaters containing near-modern and warm climate isotopic signatures. These waters have residence times of 10 to 1000 years. Below a transition zone at a depth of 500 m, groundwaters in fractures are saline, exhibit a composition approaching Ca-Na-Cl with isotopic signatures indicative of warm-climate, pre-glacial origin, with residence times of over 1 million years. These deep groundwaters are essentially stagnant over the period of concern for repository performance assessment. These groundwater characteristics at depth are indicative of long-term flow system stability, which not only ensures long groundwater residence times but also facilitates the prediction of long-term engineered barrier performance.

In 2001, OPG undertook a numerical modelling study, referred to as the Regional Groundwater Flow System Analysis. The purpose of this program is to further illustrate the influence of fundamental physical and chemical hydrogeological processes and property distributions, and flow domain boundary condtions and geometry on groundwater residence times and flow paths in a Shield like setting. The work program and interim findings are described by Sykes et al. (2002). A key intent of this work program is to explicitly address issues of flow system evolution related to; i) flow domain salinity; ii) spatially variable permeability distributions (fracture/matrix continuums); and iii) long-term climate change (i.e. glaciation). This modelling program is scheduled for completion in 2004. The work program will yield a geoscientifically reason case to understand and discuss flow system dynamics and possible strategies for the repository positioning to best take advantage of flow system characteristics.

Other aspects related to understanding flow system evolution that provide insight into repository location and/or design considerations in the DGRTP are discussed in 4.02.09.

References

Gascoyne, M., 2000, Hydrogeochemistry of the Whiteshell Research Area. OPG Report No. 06819-REP-01200-10033-R00, May 2000.
4.04.05 System Performance - Geosphere - Additional Fracture Zones PARTICIPANT COMMENTS

Atomic Energy Control Board

Information on the actual geological structure of the hypothetical geosphere is limited in that no boreholes have been drilled through the assumed position of the hypothetical vault to confirm AECL assumptions about the geosphere.... insufficient evidence is provided to rule out the possibility that other fracture zones intersect or pass close to the hypothetical vault.... a low-dipping fracture zone could exist that intersects the northwestern edge of the vault or passes immediately below the vault. [Comment 558, Source Document gov002, Page 14, Section A.2.1(i)]

OPG RESPONSE

As part of the siting and design of a candidate repository site, detailed geotechnical information on bedrock and fracture characteristics would be required from the immediate and surrounding vicinity of the vault horizon (Davison et al, 1994). Critical information such as the geometry and transport properties of intersecting fracture zones would be incorporated into the conceptual site model and evaluated as part of performance assessment activities.

Reference:

Davison C.C. et al., The Disposal of Canada's Nuclear Fuel Waste: Site Screening and Site Evaluation Technology. AECL-10713, COG-93-3, June, 1994.

4.04.06 System Performance - Geosphere - Shafts

PARTICIPANT COMMENTS

Atomic Energy Control Board

The groundwater modelling by Chan and Stanchell (1990) ... with the upcast shaft on a height of land was used as the basis for deciding that the shafts ... did not need to be included in the GEONET network for the postclosure safety assessment (Vault PRD, p. 172 and 173). However the Postclosure PRD clearly shows that the upcast ventilation shafts are located in a discharge area in the Pinawa Channel (Figure 5-15). The surface topography map for AECL's three-dimensional groundwater flow model (see Figures 5.5.2 and 5.5.3 in the Geosphere PRD) also indicates that the upcast shafts occur in a topographic low area. As such, the shafts ... were excluded from the postclosure safety assessment based on a modelling assumption that contradicts the location and layout of the hypothetical vault in the Postclosure PRD. [Comment 904, Source Document gov002, Page 54, Section C.2.5]

OPG RESPONSE

The location of ventilation shafts within, or in proximity to, surface water bodies is not considered proper mine design practice. As part of a siting and design of a candidate repository site, the location of all ventilation shafts would be selected to optimize operating performance and ensure long-term integrity once properly backfilled. Decisions on the inclusion of excavated features such as access shafts and vent raises in performance analyses will, in part, be dependent on site specific hydrogeologic conditions and on the ability to demonstrate the performance of sealing technologies. The Canadian program continues to monitor developments in sealing technology experiments such as the Tunnel Sealing experiment at the Underground Research Laboratory and the long-term ZEDEX tunnel backfill/seal experiment at the SKB Aspo Hard Rock Laboratory. In addition, preliminary 3-dimensional numerical analyses have been performed to better understand the role of repository seals and the excavation damage zone to repository integrity (Chan et. al., 1999).

References

Chan, T., M. Kolar, P.A. O'Connor, N.W. Scheier and F.W. Stanchell. 1999b. Finite-element sensitivity analysis of effects of an excavation damage zone on 129I transport from a used CANDU fuel waste disposal repository. Atomic Energy of Canada Limited for Ontario Hydro. Ontario Hydro Nuclear Waste Management Division Report No: 06819-REP-01200-0022-R00.

4.04.07 System Performance - Geosphere - Geothermal Energy

PARTICIPANT COMMENTS

Natural Resources Canada

A more likely scenario than a deep water well in saline groundwater is the development of geothermal energy, yet there is no mention of this possibility. [Comment 776, Source Document ph2gov001, Page pos3]

OPG RESPONSE

The presence of potential geothermal energy sources would be taken into consideration during a repository site selection process. The presence of such heat sources would be considered unfavourable during site selection.

4.04.08 System Performance - Geosphere - Rock Properties

PARTICIPANT COMMENTS

Environment Canada

there is also concern about ... the inadequately justified choice of the permeability value for sparsely-fractured rock [Comment 856, Source Document gov003, Page 20, Section 2.9]

Natural Resources Canada

it is unclear whether in-situ permeability values are consistent with values measured on core at the lab scale, and whether the in-situ values are consistent with the scale of the volume elements to which they are assigned. [Comment 731, Source Document ph2gov001, Page geo2]

The permeability values assigned in Table 5.3.1 for the five horizontal layers are 10-15, 10-17, 10-19, 10-20 and 10-21 m2, from the uppermost to the lowermost layer.... This decreasing trend of permeability ... contradicts that expected in granites. Laboratory permeability values ... [are] more than 10 times the assigned value for the third layer (300-1500 m). In addition, a pore structure model (Katsube and Mareschal, 1993) developed for crystalline rocks, indicates that porosities and permeabilities of those rocks are not expected to show much variation between the surface and the lower section of the upper crust. This model is supported by porosity data ... This implies that the permeability values assigned to the 4th (1500-2800 m) and 5th (2800-4000 m) layers may be too small by a factor of 10 - 104. The assigned permeability value of 10-21 m2 for the 5th layer was increased to 10-19 m2 for the sensitivity analysis (5.4.2). Based on the above-mentioned facts, this is too low, and probably should be raised by about 100 times. [Comment 732, Source Document ph2gov001, Page geo2]

Scientific Review Group

Hydraulic conductivities reported by AECL for the fractured rock do not agree with values reported for similar fractured rock at other sites, where very large variations have been observed [Comment 383, Source Document tec004, Page 057, Section 6.3.1]

The impact of non-uniform hydraulic conductivity in the rock mass, particularly the variable hydraulic conductivities associated with the excavation-damage zone is not addressed.... R-Vault 1994 fails to cite direct measurements of rock hydraulic conductivity at the URL ... Inspection of hydraulic conductivity data, obtained by packer tests, from the 350 m deep undisturbed Site Characterization and Validation (SCV) rock block at Stripa reveals that hydraulic conductivity within any borehole typically varies by 5-7 orders or magnitude over distances of several metres ... there is no reason to believe that hydraulic conductivity at the URL, or at other sites in plutonic rocks of the Canadian Shield, is much lower, and more uniformly so, than at Stripa. [Comment 212, Source Document tec004, Page 198, Section F-2.1.2]

OPG RESPONSE

OPG agrees that the assignment of permeability values to specific subregions within a site's conceptual model must be supported by reference to appropriate site-specific field and laboratory hydraulic test results. The process followed to incorporate these test results into the conceptual model must also be traceable and defendable. The permeability of fractured granite is primarily governed by fracture aperture and frequency. Variability in

fracture frequency and orientation also imparts a degree of anisotropy and heterogeneity to the permeability distribution within fractured rock. Site-specific features that tend to control variability in fracture characteristics include degree of infilling, depth, lithology, stress history and in-situ stress magnitude and orientation. In a simplistic sense, increasing overburden stresses with depth will tend to result in smaller fracture apertures and correspondingly smaller fracture-related permeabilities. The permeability of the "intact" rock matrix should ideally represent the lower bound of the range of

permeabilities assigned to a conceptual model.

As part of the Moderately Fractured Rock (MFR) experiment conducted in the URL, an array of approximately 70 packed-off borehole intervals ranging in depth from 130 to 260 m below ground surface, have undergone multiple and single step fluid withdrawal hydraulic tests (Vandergraaf et al, 2001). Coupled with a knowledge of bedrock lithology and fracture frequency, the permeability values can be grouped into three broad categories: 1) E-14 to E-16 m2 for a large sub-horizontal fracture zone, 2) E-15 to E-17 m2 for moderately fractured rock and 3) E-17 to E-21 m2 for sparsely fractured rock. These results indicate that a wide range of permeabilities can be encountered within a relatively narrow depth interval and also within similar structural units. In 2002, as part of the MFR experiment, an advanced well test analysis methodology using the Sandia National Laboratories nSIGHTS code was applied to interpret hydraulic test data (transient pressures and flow rates) (Roberts, 2002). Estimated parameters included formation hydraulic conductivities and associated flow dimensions. The uncertainty in the parameter estimates was also quantified. Through the application of rigorous field testing protocols, as well as sophisticated and traceable analysis techniques, the confidence in hydraulic parameters assigned to a geosphere conceptual model will be improved.

The spatial varibility of permeability within a flow domain, as discussed above, can markedly effect interpretation or prediction of groundwater flow rates and pathways. In developing a strategy for the synthesis of field hydrogeological data to address this issue the application of geostatistical techniques for quantitative analysis has been undertaken by the DGRTP. There are two key areas; i) realisation of spatially correlated permeability fields through conditional simulation, which honours field derived statistics; and ii) the development of geologically constrained Discrete Fracture Network models. The methodologies and examples of their application are described by Chan et al. (2001) and Srivastava (2002ab). These approaches, which are directly linked to numerical groundwater flow simulations, are intent on demonstrating the systematic and structured approach for the assignment of fracture and rock matrix permeabilites.

References

Vandergraaf, T.T et al. 2001. Moderately fractured rock experiment stage 2: large and medium scale migration experiments. Prepared by Atomic Energy of Canada Limited. Ontario Power Generation Nuclear Waste Management Division Report No. 06819-REP-01300-10020-R00.

Roberts, R.M. 2002. Moderately fractured rock experiment: well test analysis using nSIGHTS. Prepared by Sandia National Laboratories. Ontario Power Generation Nuclear Waste Management Division Report No. 06819-REP-01300-10062-R00.

Chan, T., F.W. Stanchell, R.M. Srivastava and N.W. Scheier. 2001. Stochastic conditional flow and transport simulations of tracer test no. 2 (TT2) of the moderately fractured rock experiment at the underground research laboratory: a geostatistics case study. Ontario Power Generation Nuclear Waste Management Division Report 06819-REP-01200-10039-R00.

Srivastava, R.M. 2002a. Probabilistic discrete fracture network models for the Whiteshell Research Area. Ontario Power Generation Nuclear Waste Management Division Report No. 06819-REP-01200-10071-R00.

Srivastava, R.M. 2002b. The discrete fracture network model in the local scale flow system for the Third Case Study. Ontario Power Generation Nuclear Waste Management Division Report No. 06819-REP-01300-10061-R00.

4.04.09 System Performance - Geosphere - Water Table Fluctuation

PARTICIPANT COMMENTS

Canadian Geoscience Council

there is no discussion of the annual cycles of water tables in the Canadian Shield or of variations at the 100-1000 year cycle. [Comment 1048, Source Document tec002, Page 18, Section 3.3.2]

OPG RESPONSE

The effect of water table fluctuations can be detected as transient pressure pulses to depths of several 100 metres in the low storativity fractured bedrock of the Canadian Shield (Vandergraaf et al., 2001). At the time scales of interest in performance assessment, water table variations on the 100 to 1000 year cycle are indeed of greater interest.

In 2001, OPG began undertaking research into developing a Design Basis Glacier Scenario for the Canadian Shield, which would help to better define changes in long-term climate affecting flow system boundary conditions (i.e. hydraulic gradient fields) (Peltier, 2002).

Long-term water table fluctuations associated with changing precipitation/temperature patterns and changing surface water body geometries is also of interest in the prediction of biosphere performance.

References

Vandergraaf, T.T., Kozak, E.T., Scheier, N.W., Stanchell, F.W., Ross, J.D. and P. Vilks. 2001. Moderately fractured rock experiment stage II: large and medium scale migration experiments. Prepared by Atomic Energy of Canada Limited. Ontario Power Generation Nuclear Waste Management Division Report No. 06819-REP-01300-10028-R00.

Peltier, W.R. 2002. A design basis glacier scenario. Prepared by W.R. Peltier - U. of Toronto. Ontario Power Generation Nuclear Waste Management Division Report No. 06819-REP-01200-10069-R00.

System Performance - Biosphere

4.05

4.05.01 System Performance - Biosphere - Mine Drainage PARTICIPANT COMMENTS

Atomic Energy Control Board

there is no discussion of the treatment of highly saline (high C1-) groundwaters from dewatering the repository during operations or of remedial measures for saline discharges, only a hope that their volume would be small. The possible treatment needs are not identified, and the environmental impacts that would result from saline discharges are not assessed. [Comment 676, Source Document gov002, Page 75, Section D.2.5]

Scientific Review Group

The level of production of acid mine drainage (AMD), or acidic effluent, from surface waste rock disposal sites is not addressed.... given the large quantities of waste rock to be disposed of on surface, an order of magnitude calculation of the AMD generating potential of this waste rock should have been provided. [Comment 78, Source Document tec004, Page 136, Section C-2.1.5]

The rationale for the assumption that there will be no unacceptable releases from the excavated rock is questionable. Waste rock will exist in a crushed/broken state and would exhibit much higher contaminant release rates than pre-existing, untouched Shield rocks bearing similar mineralization.... the SRG is aware of many examples where waste rock from mining operations in the Canadian Shield has been the source of contamination of both the surface environment and groundwater. This analysis could have provided additional guidance regarding the suitability of future sites (i.e. sites where contamination potential from waste rock was higher could be eliminated). [Comment 189, Source Document tec004, Page 188, Section E-3.2]

OPG RESPONSE

All waste water from the operation of a deep geologic repository would be tested and treated, if required, prior to discharge to the environment, as required by federal and provincial standards (e.g., TDS limit of 500 mg/L). For example, the Underground Research Laboratory near Lac du Bonnet in Manitoba routinely monitors and treats the water from underground operations. The Total Dissolved Solids (TDS) in the environment near the holding pond discharge are about a factor of 5 below the standard (see Ross et al. 2000, Underground research laboratory environmental monitoring program and results for 1999, AECL Report RC-261-12, URL-GEN-R026).

4.05.02 System Performance - Biosphere - Fate of Contaminants

PARTICIPANT COMMENTS

Chemical Institute of Canada

Bioaccumulation is not obviously noted as a possible pathway to exposure in the biosphere. What are the bioaccumulative properties of the radioactive containments? [Comment 1129, Source Document tec005, Page 24, Section IV.i.4]

Health Canada

the effect of human practices in localising radionuclides, such as compost piles, or animal and human waste, may contribute to total exposure through different pathways. [Comment 949, Source Document gov006, Page 14]

return of waste material to the soil compartment has been accounted for by assuming that radionuclide uptake and transfer does not deplete the concentration in the environment. However, this assumption fails to account for processes that may result in the accumulation or redistribution of radionuclides in some compartments. Redistribution could potentially be an important contributor to total dose, and should be explicitly accounted for. [Comment 989, Source Document ph2gov011, Page 07]

McMaster Institute for Energy Studies

The significance of contaminated run-off to fragile aquatic ecosystems is not addressed. Of more serious concerns, however, is the fact that the processes of bioaccumulation and biomagnification are also not addressed nor even identified. [Comment 1441, Source Document phpub033, Page 18]

Scientific Review Group

The assumption that "... radionuclide uptake and transfer in most pathways do not deplete the concentration or inventories ..." (R-Biosphere 1994: pp.208,403) ... does not account for and may mask the effect of biological activity in concentrating radionuclides in some environmental compartments or in accelerating movement of radionuclides in others. Over extended periods of time, such biological action could be important in the redistribution of radionuclides in the surface environment. [Comment 407, Source Document tec004, Page 066, Section 6.4.2]

Discussion of contaminant release to the environment from waste streams is incomplete.... The critical environmental question, however, may not be the concentrations of contaminants in waste streams, but rather total contaminant loading downstream. No consideration has been made for bioaccumulation of contaminants [Comment 80, Source Document tec004, Page 136, Section C-2.1.5]

Chemical toxicity of radionuclides to human and non-human biota are not fully addressed... the effects of bioaccumulation and biomagnification in the biota have not been addressed, although case studies of large mining operations on the Canadian Shield have been documented. [Comment 104, Source Document tec004, Page 146, Section D-2.1.8]

A major omission in the document is that there is no overall account of the fate of the contaminants in the biosphere.... it leaves hanging the question of where the contaminants actually get to. A contaminant trail through the various biological compartments would assist greatly in determining whether the selected receptors were representative, and in identifying sites of bioaccumulation (or of unexplained disappearance); and would provide information to make the postclosure assessment of impacts more realistic. It would also provide information that could assess the possible importance of effects outside the immediate area of groundwater discharge, e.g. suspended particles carried in a river and accumulated in a delta far downstream. [Comment 259, Source Document tec004, Page 229, Section H-2.2]

Another assumption that needs more explicit treatment is that radionuclide "... uptake and transfer in most pathways do not deplete the concentration or inventories ..." (R-Biosphere 1993: p.208). Thus, shortcuts, feedback, bioaccumulation and biomobility ... are considered internal to the model components and not significant in prediction of doses to the biological end-points. The existence of many biological and chemical variations within any natural system would appear to challenge this assumption, and it needs explanation. [Comment 278, Source Document tec004, Page 234, Section H-2.3]

OPG RESPONSE

The biosphere model for radionuclides in the environment (BIOTRAC2) is a conservative model which accounts for the transfer and uptake of radionuclides in fish, vegetation, animal products and humans (Zach et al. 1996). In general, the transfer coefficients from one compartment in the biosphere to another are based on empirical measurements and implicitly account for all processes, including bioaccumulation, which refers to the tendency of an organism to continue to bioconcentrate throughout its lifetime (Zach and Sheppard 1992). In addition, bioaccumulation in humans is explicitly accounted for in the derivation of the human radionuclide internal dose conversion factors.

Biomagnification refers to the occurrence of a contaminant at successively higher concentrations with increasing trophic level in the food web. Biomagnification is partially accounted considered in BIOTRAC through the use of pathways analysis (Zach and Sheppard 1992). Thus, radionuclides may accumulate through the food-chain, e.g., from soil to plants to animals. In fish, biomagnification is only implicitly considered through the use of broad aquatic concentration ratios. However, radionuclides are not usually subject to biomagnification (Swanson 1985), mainly because they are typically present in inorganic form (which are not fat-soluble).

As noted, the biosphere model uses many simplifications. For example, radionuclide losses from the soil layer due to plant uptake are not accounted for in the model. In this way, recycling of radionuclides (e.g., use of compost material in gardens, animal waste on fields, etc.) is implicitly taken into account in the model. These simplifications lead to conservative dose estimates because they cause radionuclide mass to be created in the biosphere. However, the biosphere model explicitly treats accumulation of nuclides in the important biosphere compartments, e.g., nuclide accumulation in soil due to irrigation over many years. For these reasons, we believe that any processes that have not been modelled will not contribute significantly to the predicted total dose rate of the critical group.

The critical group was selected to be a self-sufficient group living in the vicinity of the repository, where it is most exposed to the nuclide discharges from the geosphere. The biosphere model includes all important exposure pathways and uses conservative exposure parameter values. Consequently, the predicted doses for the critical group are expected to be an overestimate of the actual exposure doses for an "average" population. Exposure doses from any omitted pathways should be relatively small and predicted total doses should remain well below regulatory limits.

The fate of contaminants, after leaving the vicinity of the critical group, was not investigated in the EIS. The reason for this was that exposures to contaminants downstream from the discharge points from the geosphere would have lead to lower dose rates because of the dilution of the contaminants as they moved downstream from the discharge points. Given the increasing importance of ecological risk assessment and the expressed desire to estimate exposure doses for different critical groups, determination of the fate of the contaminants in the surface environment may be required in a future assessment. As noted such calculations are already carried out for mining operations. However, such calculations would be only be feasible after a repository site has been selected and the surface environment is defined.

Chemical toxicity of radionuclides to humans and non-human biota was addressed by comparison of predicted biosphere concentrations to background concentrations (see response to 4.02.20).

References

Swanson, S.M. 1985. Food-chain transfer of U-series radionuclides in a northern Saskatchewan aquatic system. Health Physics 49, 747-770.

Zach, R., B.D. Amiro, G.A. Bird, C.R. Macdonald, M.I. Sheppard, S.C. Sheppard and J.G. Szekely. 1996. The disposal of Canada's nuclear fuel waste: A study of postclosure safety of in-room emplacement of used CANDU fuel in copper containers in permeable plutonic rock. Volume 4: Biosphere model. Atomic Energy of Canada Limited Report, AECL-11494-4.

Zach, R. and S.C. Sheppard. 1992. The food-chain and dose submodel, CALDOS, for the assessment of Canada's nuclear fuel waste management concept. Atomic Energy of Canada Limited Report AECL-10165.

4.05.03 System Performance - Biosphere - Discharge to a River PARTICIPANT COMMENTS

Scientific Review Group

The situation in the event of discharge to flowing surface water appears to have been considered and rejected (R-Biosphere 1993: p.85).... In a river, on the other hand, the mass influx from the geosphere would generally not be distributed uniformly along the length of the river. The mass of contaminants could mix with a much smaller volume of water and higher concentrations could result in selected places. Another reason for a river to be modelled explicitly is that suspended sediments may play an important role. Contaminants, including radionuclides, often readily adsorb on suspended particles, which can become important components of aquatic food chains. These suspended particles and the biota that eat them may travel considerable distances from the point of contaminant discharge, and possibly be concentrated in deltas or spawning grounds. [Comment 262, Source Document tec004, Page 230, Section H-2.2]

OPG RESPONSE

In the EIS, dose rates to the most exposed humans are calculated. Doses to less exposed humans would be lower. Consequently, it is not necessary to consider the surface water drainage system downstream of the discharge location of groundwater from the vault, if one is only interested in doses to the most exposed humans. Nuclides flushed to downstream lakes and rivers would be diluted by additional surface runoff. Individuals living downstream of the discharge location would thus receive lower doses than members of the critical group. Although contaminants could be concentrated in deltas or spawning grounds, the concentrations at these sites would, because of dilution, be less than the sediment concentrations calculated in the EIS.

In the long-term, after attainment of steady state, nuclide concentrations in a discharge lake or discharge river would be essentially identical, if the water flows through the two water bodies are the same. That is, for the long-lived nuclides of interest, the concentration of a nuclide in a river or lake, at steady state, would be given by the ratio F(mol/a)/Q(m3/a), where F is the nuclide flow into the water body carried by the groundwater and Q is the flow rate through the water body. Consequently, exposures could be higher for a lake because of the accumulation of contaminants in lake sediments.

Given the increasing importance of ecological risk assessment and the expressed desire by many stakeholders to estimate exposure doses for different critical groups, determination of the fate of the contaminants in the surface environment may be required in a future assessment. However, such calculations would be only be feasible after a repository site has been selected and the surface environment is defined.

4.05.04 System Performance - Biosphere - Discharge to a Wetland PARTICIPANT COMMENTS

Scientific Review Group

AECL has considered that a lake will likely result in higher doses than a perennial wetland, and that BIOTRAC models wetlands implicitly (R-Biosphere 1993: p.85). Yet the wetlands contain and are underlain by some of the most active and vital parts of the terrestrial biosphere, and it is at wetland discharge points - e.g. at salt licks - where both animal species and plants may obtain the greatest concentrations of transported radionuclides. Wetlands discharge points would also appear, intuitively, to be the places where chemical contaminants (R-Biosphere 1993: p.11) will be most accessible to fauna and flora; but this subject is not mentioned in the document. AECL has recognized the possibility that radionuclides could be discharged from a wetland, river or stream, in which case the assumption of uniform mixing used in the lake model would not apply (R-Biosphere 1993: p.391), but a pathway discharging only to a wetland has not been considered separately as a scenario, and has not been modelled by BIOTRAC [Comment 281, Source Document tec004, Page 234, Section H-2.3]

OPG RESPONSE

BIOTRAC was created mainly to calculate exposures to the most exposed individuals. Consequently, the human exposure scenarios in the EIS involves a self-sufficient critical group that grows food in contaminated soil and uses water from contaminated sources. For this self-sufficient group, the most important exposure pathways involve usage of contaminated water for drinking, irrigation and drinking water for animals. In contrast, for a wetland discharge, the most important exposure pathway is likely to be due to use of the wetland for food production (Bergstrom et al. 1999). This scenario is included in some of the EIS dose calculations, for example, when sediments are used as soil.

Nevertheless, it is recognized that the EIS did not cover a sufficient range of human and biosphere characteristics of particular interest to some stakeholders. Consideration will be given, in future assessments, to calculating doses for a range of human and biosphere characteristics. Also, given the increasing importance of ecological risk assessment, it is anticipated that biospheres of importance to particular non-human biota will also be studied.

Reference

U. Bergstrom, S. Nordlinder and I. Aggeryd. 1999. Models for doses assessments. Modules for various biosphere types. SKB Technical Report TR-99-14.

4.05.05 System Performance - Biosphere - Waste Water

PARTICIPANT COMMENTS

Scientific Review Group

The consequences of organic nutrient loading in waste water originating from surface or underground sources are not discussed adequately.... Detrimental microbial processes which arise from organic nutrient loading of waste water, and which have not been given consideration by AECL, include biofouling and gas generation. [Comment 77, Source Document tec004, Page 136, Section C-2.1.5]

R-Preclosure does not provide sufficient detail on ... potential impacts of ... sewage treatment [Comment 114, Source Document tec004, Page 148, Section D-2.1.16]

OPG RESPONSE

All waste water from the operation of a deep geologic repository would be tested and treated, if required, prior to discharge to the environment, as required by federal and provincial standards. For example, the Underground Research Laboratory near Lac du Bonnet in Manitoba routinely monitors and treats the water from underground operations (see Ross et al. 2000, Underground research laboratory environmental monitoring program and results for 1999, AECL Report RC-261-12, URL-GEN-R026).

4.05.06 System Performance - Biosphere - Spills

PARTICIPANT COMMENTS

Scientific Review Group

The effects of accident scenarios on non-human biota are dispensed with summarily... Experience at uranium mines has shown that accidental spills can involve large volumes of water and tailings with potentially significant impacts What has been learned from these case study incidents? Specific design features, training issues, and spill response measures should have been described. [Comment 120, Source Document tec004, Page 149, Section D-2.2.4]

OPG RESPONSE

The accident scenarios conducted for the 1994 EIS submission were intended to be representative and bounding calculations (see PRD-Preclosure). More detailed accident scenarios on both human and non-human biota would be addressed as part of the normal evaluation of potential sites in the siting phase of the deep geologic repository program.

4.05.07 System Performance - Biosphere - Change

PARTICIPANT COMMENTS

Action Against Nuclear Waste Committee

In this century we have so altered our environmental landscape that we are told by experts that we can expect such dramatic changes as melting of the polar ice caps. How can we assume that human actions will not jeopardize the political and geological stability required to make this a safe method of disposal. [Comment 1765, Source Document phpub030, Page 1]

Canadian Geoscience Council

Attention must be paid to new discoveries in the areas of climate change and they must be incorporated into the modeling if they are shown to be important effects. [Comment 1019, Source Document tec002, Page ii, Section ES]

Ecosystem Approach Group

"Future human interaction with the biosphere is difficult to predict." This statement is a fraud. There are plenty of data and experiments to demonstrate the above deception. It is only difficult for AECL to see future human interaction with the biosphere, because they do not want to see what this interaction is right now. [Comment 2035, Source Document pub033, Page 07]

Health Canada

It is also assumed in the EIS that the future changes in the biosphere, other than human intrusion and glaciation, are not expected to lead to sudden and dramatic increases in contaminant levels, to major effects, or to acute doses. The EIS does not address the probability that such changes could lead to significant increases in the chronic radiation exposure of the critical group, and therefore a greater incidence of stochastic effects. [Comment 951, Source Document gov006, Page 14]

McMaster Institute for Energy Studies

it is stated that ... "several types of disturbances such as forest fires and insect outbreaks occur" which can affect forest vegetation development. The discussion is a very general description of a few of the various important biological and ecological processes affecting forest/vegetation development. A more derailed description and analysis of these processes is warranted as whole ecosystems can change after such disturbances as flood, or extreme temperature changes.... such a change could have implications for other aspects of the concept implementation program such as monitoring. [Comment 1437, Source Document phpub033, Page 15]

Northwatch (Richardson)

The techniques for modelling geological, climatic and perhaps even more importantly, social evolution into the far future, over the timescales required in nuclear waste disposal, are also proving to be intractable to date. [Comment 1559, Source Document ph3pub088, Page 10]

Scientific Review Group

during the next 10,000 years ... the natural environmental conditions may change considerably. These changes are likely to affect most markedly surface drainage, lake volumes, land cover, soils development, and indigenous terrestrial and aquatic biota. Environmental changes caused by humans, such as alteration of climate, land cover, drainage systems, soil and water chemistry, and indigenous and introduced biota, which are likely but at present impossible to predict with confidence, may be added to these expected natural changes. Superimposed on these changes there is the additional possibility or likelihood of significant changes in the type and intensity of human use of the lands and waters, and changes in the human valuation of components of ecosystems or geosphere in unforeseen ways. [Comment 331, Source Document tec004, Page 039, Section 5.6]

The possibility of significant climate change, leading toward re-establishment of continental glaciation or a period of marked desiccation, in the southern Canadian Shield in the next 10,000 years cannot be ruled out with confidence. [Comment 333, Source Document tec004, Page 040, Section 5.6]

The other important biological component neglected by BIOTRAC is ... the activities of humans.... the BIOTRAC model ... should at least be able to examine a wide range of potential human situations and human-instigated activities that might affect the environment, and the vulnerability of humans themselves. [Comment 396, Source Document tec004, Page 064, Section 6.4.2]

The assumption that the overall natural state of the physical and biological environment will remain essentially unchanged for the next 10,000 years reflects general opinion among earth scientists with regard to the likely onset of continental glaciation and changes of land elevation (R-Biosphere 1994: pp.349-360), but no evidence or arguments are given for assuming that the terrestrial and aquatic biota will remain constant during the same period. No evidence is given about the significance of the considerable changes in terrestrial or aquatic biota of the region in the past ten thousand years, and what this recent history may indicate about future change. [Comment 405, Source Document tec004, Page 066, Section 6.4.2]

The assumption that future human-caused alteration of the landscape, hydrology, or regional biota (native or introduced) may be neglected in scenarios of future discharge of radionuclides is probably unrealistic; and it would have been useful to show how BIOTRAC could accommodate an anthropologically-changed surface environment, rather than assume no change... uncertainty in prediction is no reason to assume that there would be no changes. It would be preferable to show how the modelling and prediction methods could serve to show the consequences of the various changes, as more data or better scenarios become available. [Comment 406, Source Document tec004, Page 066, Section 6.4.2]

Many assumptions made in R-Biosphere should have been discussed from the point of view of whether they are likely to remain valid, or to become implausible or even counter-productive, when extended over 10,000 years. [Comment 408, Source Document tec004, Page 066, Section 6.4.2]

Although there is no way of knowing where global climate change scenarios will lie, a scenario involving either a raised or a lowered watertable could have been considered. [Comment 439, Source Document tec004, Page 079, Section 6.6.2]

The SRG does not agree with the screening argument that eliminated global warming from consideration. Global warming could lead to a change in flora, fauna and the behaviour of the critical group [Comment 154, Source Document tec004, Page 170, Section E-2.1.4]

the authors deal with transitional processes and describe usefully the changes that may take place; then they largely dismiss them as either too uncertain to be treated seriously or too complex (i.e. too expensive) to model.... it should be possible to develop some plausible scenarios of a range of future environments and human activities and estimate usefully their likely effect on those aspects of landscape and biosphere that are relevant to potential impact from escaping radionuclides.... If the parameters for a range of future scenarios fell within the range of probability density functions already in place, the central scenario would be confirmed as adequate on the basis of present knowledge and informed speculation. If on the other hand it was evident that some predicted doses stretched the probability density functions to unreasonable lengths or lay outside them, then either a number of alternate scenarios or a change in the model would be indicated. In either case, some prediction of future changes in human effects or biological successions (R-Biosphere 1993: pp.56, 59, 350, 361) would test the robustness of BIOTRAC and enhance the credibility of the postclosure assessment. [Comment 282, Source Document tec004, Page 235, Section H-2.3]

the environmental and biological processes and forces being modelled are taken to be steady-rate, unchanging over 10,000 years or more [Comment 293, Source Document tec004, Page 238, Section H-3]

no change in environmental conditions or biological response is allowed for [Comment 294, Source Document tec004, Page 238, Section H-3]

the SRG's concerns about the flexibility and robustness to convincingly demonstrate safety have not been addressed. AECL has still modelled the radionuclide transport in the surface environment under the assumption that no major changes in topography are likely to occur during 10,000 years, that changes in climate, surface water flow patterns, and soils will be negligible, and that vegetation types will be within the range observed at present. [Comment 545, Source Document tec004a, Page 18, Section 3]

United Church of Canada

There is a need to examine the Concept for both optimistic and pessimistic scenarios for future generations in terms of technical capabilities, resource availability, social stability, etc. [Comment 1736, Source Document phpub124, Page 3-15, Section 3]

OPG RESPONSE

By placing used fuel in a geologic repository 500m or more below the surface, the fuel is isolated from the biosphere and inadvertent human actions. Thus, the fuel in the repository would be better protected from changes to either the surface environment or human society.

At present there are no credible models available to predict human activities. Thus, in the EIS and SCS, the characteristics of the critical group are based on present day human behaviour. This is the approach used in the international nuclear waste management community. The AECB (1987) regulatory policy statement has also recognized these difficulties and states: "When considering potential exposures in the future, the precise identification of critical groups and their lifestyles is not possible, ... In these circumstances, the individual risk requirements in the long term should be applied to a critical group of people that is assumed to be located at a time and place where the risks are likely to be the greatest. ... Definition of the lifestyle of the hypothetical critical group of people should be based on present human behaviour using conservative, yet reasonable assumptions."

Other organizations also recognize the difficulty in predicting human behaviour in the long term. The IAEA peer review of the biosphere modelling program of the Yucca Mountain Site (IAEA 2001) recommended the calculation of a number of complementary performance indicators (e.g., drinking water dose, nuclide concentrations in soil, etc.) that are less dependent on the assumptions concerning human habits. The OPG Third Case Study will evaluate some alternative indicators (Gierszewski et al. in prep.)

In the development of BIOTRAC, the question of environmental and ecological changes was evaluated (AECL, 1996). This led to the distinction between fluctuating and transitional processes. Fluctuating processes involve relatively rapid variation about some mean condition (e.g., seasonal temperature changes); transitional processes involve periodic or non-periodic changes such as continental glaciation. Fluctuating processes are considered in BIOTRAC through parameter variability (Davis et al. 1994). Thus, each simulation represents a slightly different biosphere.

Future environmental and ecological conditions are difficult to define, e.g., there is still disagreement about the extent of global warming caused by human activities. However, glaciation was identified as one of the most important transitional processes and a separate assessment (Davis et al. 1993, p. 349-360) was carried out even though glaciation will likely not happen within the next 10 000 years. The analysis indicated that predicted doses would not much be affected by the changes induced by glaciation. Perhaps this analysis should have been presented in the Postclosure assessment document (Goodwin et al. 1994). It is accepted that the assumptions made in BIOTRAC should have been discussed from the point of view of whether they are likely to remain valid over 10000 years.

It is recognized that the EIS did not cover a sufficient range of human and biosphere characteristics of particular interest to some stakeholders. In future assessments, consideration should be given to calculating human and non-human doses for a range of human and biosphere characteristics. These calculations should perhaps include the biospheres predicted to occur following global warming or glaciation cycling.

Finally, it is expected that modelling methods will continue to evolve and there will be a greater variety to choose from by the time that assessments are carried out for a proposed disposal site. When the time comes, the most appropriate methods for the conditions at a proposed disposal site would be used.

References

Atomic Energy Control Board (AECB). 1987. Regulatory policy statement. Regulatory objectives, requirements and guidelines for the disposal of radioactive wastes - long term aspects. AECB Regulatory Document R-104, 1987 June 5.

Atomic Energy of Canada Limited (AECL). 1996. Response to Request for Information. Atomic Energy of Canada Limited Report AECL-11602.

Davis, P.A., R. Zach, M.E. Stephens, B.D. Amiro, G.A. Bird, J.A.K. Reid, M.I. Sheppard and M. Stephenson. 1993. The disposal of Canada's nuclear fuel waste: The biosphere model, BIOTRAC, for postclosure assessment. Atomic Energy of Canada Limited Report, AECL-10720.

Gierszewski, P. et al. In preparation. Third Case Study - Postclosure safety assessment. Ontario Power Generation Report 06819-REP-01200-10109-R00.

International Atomic Energy Agency (IAEA). 2001. An international peer review of the biosphere modelling programme of the US Department of Energy's Yucca Mountain Site Characterization Project.

4.05.08 System Performance - Biosphere - Sediment to Fish Pathway PARTICIPANT COMMENTS

Scientific Review Group

apparently because of lack of data, the possibility of direct transfer of radionuclides from lake sediments to fish is not explicitly considered; yet this could conceivably be an effective short-cut in the contaminant pathway. [Comment 398, Source Document tec004, Page 065, Section 6.4.2]

OPG RESPONSE

External fish doses resulting from immersion in water and sediments are included in BIOTRAC (Davies et al. 1993, p. 372-373). Hence, in the EIS, fish are exposed to external radiation doses from the sediments.

In the EIS, nuclide concentrations in fish are calculated using a fish/water concentration ratio Bj, with j = FW FISH (Davies et al. 1993, p. 217). Since the Bj values are derived from field observations, the effect of the direct transfer of radionuclides from lake sediments to fish would be implicitly included in the derived values of Bj, assuming that the nuclide concentrations in sediments and water column are in quasi-steady-state. Since lake characteristics are site specific, this may indicate the need to use site specific fish/water concentration ratios in the dose calculations.

If site-specific Bj values are unavailable, another approach for taking into account exposure to lake sediments would be to assume that, for a fraction of their lifetime, fish are exposed to sediment porewaters rather than to the overlying lake water. Nuclide concentrations in fish flesh would then be calculated using the Bj value and the weighted average of the sediment porewater and lake water concentrations, where the weighting factor is the fraction of the time fish spend in each media (Hart and Garisto 1997).

References

Davis, P.A., R. Zach, M.E. Stephens, B.D. Amiro, G.A. Bird, J.A.K. Reid, M.I. Sheppard and M. Stephenson. 1993. The disposal of Canada's nuclear fuel waste: The biosphere model, BIOTRAC, for postclosure assessment. Atomic Energy of Canada Limited Report, AECL-10720.

Hart, D. and F. Garisto. 1997. An ecological assessment model for prediction of population level impacts at AECB licensed facilities. Beak International Inc. Report 20476.1 for Atomic Energy Control Board.

4.05.09 System Performance - Biosphere - Retention in the Hypolimnion PARTICIPANT COMMENTS

Atomic Energy Control Board

it is assumed that the contaminants are rapidly and uniformly dispersed throughout the lake volume upon reaching the lake. For fish and benthic organisms, it would be more conservative to assume that the contaminants are retained within the hypolimnion of a stratified water column. [Comment 650, Source Document gov002, Page 63, Section C.5.2]

OPG RESPONSE

It would be more conservative to assume that the contaminants are retained within the hypolimnion of a stratified water column. However, in most shield lakes, the water column does not remain stratified throughout the year but turns over (i.e., becomes well-mixed) after the temperature gradient weakens (in spring and fall). Further, shallow lakes, which make up a large portion of Canadian Shield lakes, do not stratify during the ice-free season. Thus, because of the long exposure times, the lake can, on average, be considered to be well-mixed for the calculation of human and non-human doses.

4.05.10 System Performance - Biosphere - Sediment Concentrations PARTICIPANT COMMENTS

Atomic Energy Control Board

Sediment concentrations would build up in time as is the case for soil concentrations, and this could be significant for organisms inhabiting sediments or the sediment surface. This issue has not been considered in dose assessments to aquatic biota (Preclosure PRD, Section 9.2.1.2, p. 9-3). [Comment 674, Source Document gov002, Page 75, Section D.2.3]

OPG RESPONSE

In the preclosure assessment, nuclide concentrations in sediments are calculated from the nuclide concentration in water using a radionuclide distribution coefficient (Russell 1993). This assumes that the nuclides in the water and sediment are at equilibrium. Hence, any build up of radionuclides in the water column would also be reflected in the sediments. However, in the preclosure assessment, doses to aquatic biota from external exposure to contaminated sediments (groundshine) are neglected (Russell 1993, p 28). Since groundshine or sediment immersion doses are included in the calculation of fish doses for the postclosure period (Davies et al. 1993, p.217), for consistency, consideration should be given to including these doses in the calculation of the total fish doses for the preclosure period.

References

Davis, P.A., R. Zach, M.E. Stephens, B.D. Amiro, G.A. Bird, J.A.K. Reid, M.I. Sheppard and M. Stephenson. 1993. The disposal of Canada's nuclear fuel waste: The biosphere model, BIOTRAC, for postclosure assessment. Atomic Energy of Canada Limited Report, AECL-10720.

Russell, S.B. Radiological pathways analysis for chronic emissions for the used fuel disposal concept. Support document A-2 to the preclosure environmental and safety assessment. Ontario Hydro Report No. N-03784-939998 (UFMED)

4.05.11 System Performance - Biosphere - Food Chain Pathways PARTICIPANT COMMENTS

Health Canada

several exposure pathways not modelled explicitly [may not be] accounted for implicitly in the parameter distributions.... the consumption of dairy products other than milk ... the consumption of fruit or juice from fruit trees ... Surface vegetation such as lichens ... ingrowth from these radionuclides for animals and livestock [Comment 947, Source Document gov006, Page 13]

several exposure pathways, although not modelled explicitly, have been accounted for implicitly through the use of parameter distribution functions. This assumption, however, may not be correct for such pathways as the consumption of dairy products other than fresh milk (such as cheese, etc), which may in fact have greater radionuclide accumulation factors, and could contribute a significant portion of the diet. [Comment 988, Source Document ph2gov011, Page 07]

McMaster Institute for Energy Studies

If radioactive or toxic contaminants have the potential to enter the root zone and be taken-up by plants, nematodes and other soil fauna, then a more careful analysis of soil-water-plant interfaces is warranted from both a human health and natural environment perspective. [Comment 1442, Source Document phpub033, Page 18]

OPG RESPONSE

The food-chain in the EIS includes ingestion of milk and dairy products, which are represented by the TE MILK food type (Davis et al. 1993, p.205). The transfer factors used to determine the radionuclide concentrations in TE MILK were assumed to be equal to those for milk, for which much data are available. However, the validity of using milk transfer factors for milk products was not discussed in the EIS and further investigation of this point is warranted, since radionuclide concentrations in milk products could be higher than those in milk (Till and Meyer, 1983).

In the EIS biosphere model, a generic plant was used to model all plants. Since food-chain transfers were treated probabilistically and transfer parameters were very broadly distributed, it was argued that the EIS food-chain model implicitly includes ingestion of many different food-types. The current versions of this biosphere model (SCC404 and later) explicitly separate plant types into garden and forage field types, which recognizes a basic degree of differences that can affect the food chain pathway.

Explicit calculations using 11 alternative human lifestyles, such as all-meat and vegetarian (Zach et al. 1996) indicated that the range of EIS probabilistic dose results included those for the 11 alternative lifestyles. It was concluded (Zach et al. 1996) that the EIS assessment was representative of the full spectrum of diets and lifestyles that might be encountered on the Shield.

Since uptake of radionuclides by plants are modelled using transfer data (plant/soil concentration ratios) derived from actual field experiments, explicit consideration of the soil-water-plant interfaces is not required.

References

Till, J.E. and H.R. Meyer. 1983. Radiological Assessment. A Textbook on Environmental Dose Analysis. U.S. Nuclear Regulatory Commission Report NUREG/CR-3332 and ORNL-5968.

Zach, R., J.G. Szekely, G.A. Bird, W.C. Hajas, C.R. Macdonald and S.C. Sheppard. 1996. Alternative human characteristics and lifestyles in the BIOTRAC biosphere model for assessing Canada's nuclear fuel waste disposal concept.

4.05.12 System Performance - Biosphere - Suspended Sediment in Lake Water

PARTICIPANT COMMENTS

Health Canada

The surface environment model does not address the issue of ingestion of suspended sediment in drinking water from the lake. [Comment 948, Source Document gov006, Page 14]

OPG RESPONSE

The surface water model used in BIOTRAC does not differentiate between nuclides dissolved in the water and nuclides adsorbed on suspended particles in the water. Rather, an equation describing the total nuclide concentration in the water column (dissolved + adsorbed) is derived (Davis et al. 1993, p. 89). Therefore, the water concentrations used in the calculation of water ingestion doses include contributions from nuclides adsorbed on suspended material and, consequently, the water ingestion doses also include contributions from ingestion of suspended particles.

References

Davis, P.A., R. Zach, M.E. Stephens, B.D. Amiro, G.A. Bird, J.A.K. Reid, M.I. Sheppard and M. Stephenson. 1993. The disposal of Canada's nuclear fuel waste: The biosphere model, BIOTRAC, for postclosure assessment. Atomic Energy of Canada Limited Report, AECL-10720.

4.05.13 System Performance - Biosphere - Sorption in the Mixed Sediments PARTICIPANT COMMENTS

Atomic Energy Control Board

it is assumed that radionuclides will reach the sediment through the deposition of contaminated suspended particulates from the water column. However, higher sediment concentrations would result from radionuclides being retained by the sediment as the groundwater is discharged from the geosphere. [Comment 649, Source Document gov002, Page 62, Section C.5.2]

Scientific Review Group

In the attempt to be conservative, the simplified model does not consider some processes that may be important.... The assumption of no sorption in the mixed sediments avoids consideration of processes that are often considered important for immobilization of radionuclides to that extent it is conservative. But in many lakes it has been found that shallow sediments are the primary source of radionuclides in aquatic food chains, and may lead to bioaccumulation or to direct transfer to humans (R-Biosphere 1993: p.217). It would appear that radionuclide sorption in mixed sediments should be considered explicitly. [Comment 263, Source Document tec004, Page 231, Section H-2.2]

OPG RESPONSE

Sediments in a lake are divided into two layers: a mixed-sediment layer and a compacted-sediment layer. The mixed-sediment compartment represents the top sediment layer, a few centimetres thick, which is continually mixed by the action of the water and aquatic organisms.

It is true that the mixed-sediment model in BIOTRAC does not explicitly treat radionuclide adsorption. However, the effects of nuclide sorption are implicitly included in the model. The nuclide concentration in mixed-sediments is calculated from the mass-balance equation for the mixed sediments (Davis et al. 1993, p. 91). The nuclide flow into the mixed-sediments is equal to the rate of loss of nuclides from the water column, which is derived from studies of nuclide mass flows in Shield lakes. In reality, these nuclides flows likely arise due to the deposition of suspended particles containing adsorbed nuclides. Consequently, although not explicitly present in the model, the effects of nuclide sorption onto sediment particles has been incorporated into the model.

Nuclides in the mixed-sediment layer are assumed to come entirely from the water column (see above). Nuclide concentrations in the compacted sediment layer, within the region of groundwater discharge, are assumed to arise entirely through sorption from upward-moving groundwater. Since compacted sediments are simply mixed sediments that have been buried, the compacted sediment layer will contain some nuclides that originated in the mixed sediments. However, this contribution is neglected in calculating the compacted-sediment concentration since in most cases it is expected to be very much less than the contribution from sorption from upward-moving groundwater.

When the sediment is used as soil for growing food or to calculate external fish doses due to immersion in sediment, a depth-weighted average of the concentrations in the two sediment layers is taken to give an effective sediment concentration in the top 30 cm. Hence, the biosphere model does include doses resulting from absorption by sediments of nuclides in the groundwater stream passing through the sediment layer. However, the approach used in BIOTRAC may not be conservative, since the mixed-sediment layer does not absorb nuclides from the groundwater stream passing through the sediments. The degree of non-conservatism should be ascertained.

References

Davis, P.A., R. Zach, M.E. Stephens, B.D. Amiro, G.A. Bird, J.A.K. Reid, M.I. Sheppard and M. Stephenson. 1993. The disposal of Canada's nuclear fuel waste: The biosphere model, BIOTRAC, for postclosure assessment. Atomic Energy of Canada Limited Report, AECL-10720.

System Performance - Receptors

4.06

4.06.01 System Performance - Receptors - General PARTICIPANT COMMENTS

Scientific Review Group

the microscopic and macroscopic biota throughout the entire groundwater path from the vault to the surface ... including humans, are the receptors whose health, productivity, and diversity is to be protected from harmful impact from escaping radionuclides. [Comment 334, Source Document tec004, Page 040, Section 5.6]

The potential impact of a disposal facility on aboriginal people, and the land on which much of the aboriginal lifestyle is based, should have been discussed more fully and integrated into the preclosure performance assessment [Comment 105, Source Document tec004, Page 147, Section D-2.1.9]

The regulatory guidelines which instruct that a mythical group of humans who live right over the groundwater discharge from the vault for one hundred centuries is to be used as the receptor for calculations of risks and consequences (R-Biosphere 1994: p.17) may not be adequate for assessment of the potential effects on the environment or people, from such a large amount of contaminating material over such a long period of time. It may be prudent to examine also the possible collective risk to human populations in a broader sense, to a range of potential life styles and populations, or to those living downstream, and to ecosystems from chronic small doses below regulatory limits. Such a broader analysis would, at the least, provide a basis for comparing whether humans and wildlife in the vicinity of the discharge points are indeed at greatest potential risk; and would aid in the definition of boundary conditions and receptors when it is necessary to move from a generic situation to a specific candidate disposal site [Comment 253, Source Document tec004, Page 225, Section H-S]

The selection and definition of the critical group of human potential receptors of transported radionuclides and of the target organisms in the non-human components of the biosphere is inadequate to deal with the range of situations that an assessment of the safety of a nuclear fuel waste disposal system will be called upon to address. [Comment 269, Source Document tec004, Page 232, Section H-2.3]

OPG RESPONSE

Future safety assessment will look in further detail at the distribution and fate of radionuclides released to the biosphere, and will also consider various groups who might be exposed.

4.06.02 System Performance - Receptors - Humans

PARTICIPANT COMMENTS

Atomic Energy Control Board

AECL does not justify the selection of the self-sufficient farm household as the critical group. AECL should discuss the various possibilities for the critical group, and provide reasoned arguments and/or assessments to show that the risks would be expected to be greatest for the self-sufficient farm household.... AECL should have considered scenarios where a well or well-field is used to supply water for a town or village. [Comment 653, Source Document gov002, Page 63, Section C.6.1]

the critical group is located 1500 m away from the UFDC but the highest environmental concentrations are expected to occur 200 m from the UFDC (Preclosure PRD, p. 9-3); this is therefore not a conservative assumption. [Comment 669, Source Document gov002, Page 74, Section D.2.1]

Health Canada

Both the Preclosure and Postclosure Assessments evaluate the health impact to a member of the critical group, which they define as a rural household on a subsistence farm. This does not take into consideration the lifestyle of an aboriginal person who might be much more dependent on hunting, fishing, and gathering wild plant foods. [Comment 931, Source Document gov006, Page 07]

The EIS uses infants and adults to represent the general population for risk estimation purposes.... the use of the infant receptor should have been better justified [Comment 973, Source Document gov006, Page 19]

it is our view that the members most likely to be exposed should represent the critical group, and from the EIS these would appear to be the aboriginals unless, of course, a decision would be taken to exclude them from any chosen site.... Would it perhaps be fruitful to conduct varying scenarios, with the aboriginals constituting at least one of a number of critical sub-groups? [Comment 981, Source Document gov006, Page 31]

it may be necessary to show the effects on several different groups demonstrating different types of concerned communities. For example, an aboriginal community deriving most of its livelihood from hunting and food gathering may have quite a different pattern of exposure from that of rural non-aboriginal residents.... Also, can one afford the possibility that an urban community, with all kinds of boreholes and excavations, may be built on the site 1000 or more years in the future? [Comment 987, Source Document ph2gov011, Page 06]

when risk estimation is conducted for foods, it is preferable that all segments of the population be considered, not only infants or toddlers. Although these latter two groups may represent the population most at risk, pregnant women and their unborn children should also be singled out since some of the chemical contaminants could be toxic to fetuses (e.g. mercury). [Comment 1008, Source Document ph2gov011, Page 16]

National Action Committee on the Status of Women

The most glaring deficiency in the EIS is the complete absence of any reference to or analysis of the particular potential ... health impacts of this project on women [Comment 1279, Source Document pub026, Page 21, Section 7.1]

AECL seems to follow the trend of gender bias in scientific research in this EIS, as evidenced by its complete lack of literature review on gender issues, and its failure to attempt to determine the potential impacts of the proposed concept on women's health. AECL settles instead for meeting standards without exploring whether or not those standards are adequate for populations other than those typically used to determine them. [Comment 1288, Source Document pub026, Page 30, Section 7.2.7]

The EIS has very little if anything to say about women workers. The occupational health and safety issues that concern women in the deep disposal project are not directly addressed. The proposal in fact makes only the rarest reference to women's problems, whether occupational or otherwise." [Comment 1292, Source Document pub026, Page 31, Section 7.3]

None of the potential health effects of the proposed concept on women workers described here or in Appendix A were addressed in the EIS [Comment 1293, Source Document pub026, Page 32, Section 7.3.1]

Northwatch (Lloyd)

Additional Key Information Deficiencies Identified in Phase II Technical Hearings (June 1996) ... - identification and assumptions about the "critical group" [Comment 1547, Source Document ph2tec045, Page 24]

Nuclear Awareness Project

[Describe] the expected human health impacts of a range of mishaps and accidents ... for the implementation stage of the vault and the post-decommissioning stage of the vault, including - individual radiation doses (for children, foetuses, women and men) ... for each scenario [Comment 1937, Source Document pub035, Page 4, Section B]

OECD/NEA Review Group

the Group considered that the critical group selected for the analyses may well be unnecessarily conservative. It could be re-evaluated to ensure that it is based on both 'cautious and reasonable assumptions' (as formulated in the guidelines, ICRP-46). [Comment 1219, Source Document tec001, Page 11, Section 3.3]

Scientific Review Group

a self-contained rural life style ... To imagine such a life style for the next 10,000 years strains credulity, but it may be warranted for modelling purposes.... confidence in this assumption would have been improved if other human scenarios had been included for comparison. [Comment 404, Source Document tec004, Page 066, Section 6.4.2]

The size and nature of the critical group is of concern. Demographic projections for the near future suggest that the population will double by 2050. Therefore, it may also have been appropriate to consider an urbanized site as well as a rural setting [Comment 150, Source Document tec004, Page 170, Section E-2.1.4]

the critical group should also be defined as a larger population, because aside from the multiplication of genetic effects within a larger population, there is a significant possibility that a large urban population, rather than a small family, will reside in the critical location.... Demographic, economic, meteorological, sociological etc. considerations should have been used to estimate the continuity of the population type, site and customs at the location. [Comment 162, Source Document tec004, Page 176, Section E-2.1.5]

Explicit consideration of an aboriginal critical group is advisable. For example, parameters such as the intake of country foods such as fish by aboriginal people is larger than that used in the Biosphere model. [Comment 489, Source Document tec004, Page 176, Section E-2.1.5]

assuming that the most critical group of humans or animals are those that live right on top of the area of discharge may not necessarily be the most conservative scenario. [Comment 494, Source Document tec004, Page 231, Section H-2.2]

There is an uncritical assumption that the typical human group used for illustration by the AECB in 1987 in its statement of regulatory objectives, requirements and guidelines (AECB R-104 1987) will constitute the people and lifestyle most vulnerable to harm from a leaking depository (R-Biosphere 1993: Section 1.5.4). No other assemblage of people, or lifestyles over the next hundred centuries, has been considered by AECL in its analysis. [Comment 270, Source Document tec004, Page 232, Section H-2.3]

The doses used in the food-chain and environmental models (R-Biosphere 1993: p.227, 239) ... are considered to be representative of both sexes and all age groups. The validity of this assumption, when applied to contamination at a very low level over very long periods of time, must be questioned.... it would have been good to see trial calculations to determine the possible difference for, say, an infant or another species. The SRG notes that the PREAC model does deal specifically with doses to infants, (R-Preclosure 1994: p.6-6), as required by the AECB (AECB R-104) (for persons under the age of 16) and by CSA 1987 (for infants). [Comment 279, Source Document tec004, Page 234, Section H-2.3]

OPG RESPONSE

Guidance on critical group is given by ICRP (ICRP 81, 2000) where it is recommended attention focus on highest risk as well as highest dose. This, as well as points brought forward in the hearings, suggests that the distribution of radionuclides and possible release points should be examined in a future site-specific assessment. Possibilities for the critical group should be examined, e.g. exposure via a well versus a lake; the possibility of an urbanised setting in the future vs self-sufficient farming and aboriginal life-style groups. Additional examination of critical groups for disposal scenarios is alos taking place as part of IAEA progams.

The makeup of the critical group should also be considered with respect to gender and age. ICRP state that since radionuclides releases are expected to be relatively constant over time (at the time of exposure), it is sufficient to average dose and risk over a lifetime and hence calculations for an adult suffice. This does not address the fact of the risk criterion being an annual criterion. However, for many of the nuclides and pathways of interest, the 'annual' dose calculated and used in calculation of risk is actually a dose commitment and is received over a number of years over which time the body and individual organs grow. Some averaging may therefore be appropriate. This is an aspect which could be examined further. The age distribution for chemical contaminants should also be examined further.

Regarding mishaps, it is OPG's intent to examine a range of 'what-if' scenarios as part of postclosure safety assessment. Operational safety assessment (I.e. of the preclosure stage) will also be required to obtain a construction license from CNSC, and would address a range of potential accidents.

4.06.03 System Performance - Receptors - Natural Environment

4.06.03.01 System Performance - Receptors - Natural Environment - General PARTICIPANT COMMENTS

Atomic Energy Control Board

the proponent should have attempted to identify the organisms and life stages most likely to receive the highest doses due to the ecological niche in which they are found (e.g., feeding habits, part of the environment occupied during sensitive life stages, etc.). Significant exposure pathways for potential VECs have not been identified and the proponent does not provide any information on how these would be identified when the site assessment stage is reached (Preclosure PRD, pp. 6-13 to 6-15). An ecological risk assessment methodology needs to be followed. [Comment 668, Source Document gov002, Page 74, Section D.2.1]

the proponent provides little information to suggest that they are aware of methods that provide criteria to identify VECs that are ecologically important species, which are species that play a significant role in structuring ecosystems or in the function of a given ecosystem (Preclosure PRD, Section 10.2). The references (e.g., Beanlands and Duinker 1983) used as a basis for the document's "Ecological Perspective" are somewhat outdated (mainly from the 1970s and early 1980s). Methods and criteria to identify ecologically important species, and to choose effects indicators and measurement endpoints for environmental effects monitoring programs, have been extensively researched in the last five years, and would be relevant to the preclosure assessment. [Comment 673, Source Document gov002, Page 74, Section D.2.2]

Environment Canada

A commitment to a broad range of ecological measurement endpoints should be made, and examples of such endpoints should be identified and justified. Consideration should be given to the fact that an important endpoint may be remote from the point of discharge (e.g. at a river delta). The document does contain a diverse list of assessment endpoints and potential measurement endpoints, however, it is not clear that any of these is proposed for use with the exception of a commitment to predict radiological dose to biota. The generic biota considered may not represent the full range of valued ecosystem components. [Comment 886, Source Document gov003, Page 32, Section 2.15]

In the BIOTRAC and SYVAC3 models, ecological receptors are identified in broad categories, but it is not clear what potential effects might be deemed relevant. [Comment 887, Source Document gov003, Page 33, Section 2.15]

Scientific Review Group

the acceptability and applicability of AECL's concept, and the validity of the results of the predictive techniques to assess the long-term performance and safety of the concept should be evaluated in terms of protection of the natural environment, and not just in terms of human health. [Comment 137, Source Document tec004, Page 162, Section E-2.1.1]

The model, and the discussion of it in the document, do not give guidance on how decision makers or the public should value the biosphere or any components of it with regard to issues related to nuclear waste disposal, and such guided valuation will be essential if the public or authorities are to commit funds over an extended period to prevent damage to the environment. It is the potential, no matter how small, for damage to valued components of the biosphere, including humans, that lies behind the whole Environmental Assessment Process and the popular concern about the existence and the disposal of nuclear fuel waste. [Comment 252, Source Document tec004, Page 223, Section H-S]

no attention is given to invertebrate fauna or non-vascular plants, or to microbiota, mainly on the excuse that data are inadequate (R-Biosphere 1993: p.366). But it is these organisms which largely control ecosystem functioning and response to disturbance or contamination. [Comment 274, Source Document tec004, Page 232, Section H-2.3]

United Church of Canada

The EIS [AECL, 1994] fails to adequately explore the potential impact of the Concept on biota; therefore it fails to adequately address issues of prevention of impact, detection of impact and protection of biota. There is a brief mention of possible special consideration for endangered, threatened or rare species but the fundamental issues of the protection of wildlife, wilderness habitat and areas of high biodiversity and biological productivity are not presented. [Comment 1744, Source Document phpub124, Page 3-21, Section 3]

OPG RESPONSE

Any future site-specific safety assessment and environmental assessment would be accompanied by consideration of ecological effects and protection of non-human biota using appropriate Ecological Risk Assessment methods, including identification of VECs, surveys, endpoints, effects and criteria (see also response to 3.03.06). This could build on work OPG has carried out for the Nuclear Generating Stations, and that done by AECL particularly for the Chalk River site.

OPG is aware of developments in treating non-human biota and is studying how to best incorporate them into models. Some initial examination of possible reference biota for ongoing non-site-specific assessments has been carried out (Sheppard 2002).

Reference:

Sheppard, S.C. 2002. Representative biota for ecological effects assessment of the deep geologic repository concept. Prepared by ECOMatters Inc. Ontario Power Generation, Nuclear Waste Management Division Report 06819-REP-01200-10089-R00.

4.06.03.02 System Performance - Receptors - Natural Environment - Generic Organisms

PARTICIPANT COMMENTS

Atomic Energy Control Board

Although the choice of generic biota is useful in a general assessment, AECL should have attempted to identify the organisms and life stages that would potentially receive the highest doses because of their diet or habitat, and to orient their assessment towards those organisms or life stages. [Comment 651, Source Document gov002, Page 63, Section C.5.3]

the proponent has not provided any information on the most significant pathways of exposure for biota and has, therefore, not shown that herbivores and granivores would be the most exposed. It is possible that insectivores and birds (eg. ducks) feeding on aquatic plants and benthic invertebrates could receive the higher doses. [Comment 670, Source Document gov002, Page 74, Section D.2.1]

Fish are assumed not to be exposed to groundshine. However, in the case of bottom-feeding fish, external exposure from contaminated sediments may be an important pathway of exposure. [Comment 671, Source Document gov002, Page 74, Section D.2.1]

Scientific Review Group

The estimation of dose rate to generic nonhuman biota is insufficient and unsatisfying. Explicit incorporation of selected fauna and flora typical of the Shield (especially those with biological and ecological characteristics that would produce higher-risk scenarios to those of generic organisms) would have been preferable. There are minimal and unsatisfactory relationships established between animals and plants and the generic components of the system model. The range of dose rates for the generic organisms should be furnished and compared to the range of dose rates from natural sources in Shield environments in Canada. In particular, the dose rates should have been compared to doses known to have caused effects in the most sensitive groups of Shield species. This would have been more convincing. [Comment 460, Source Document tec004, Page 085, Section 6.6.5]

Use of generic non-human biota would have been more acceptable had the PDFs for these generic organisms been refined to reflect wildlife and wild vegetation rather than just assuming that domestic plant and animal parameters were largely representative. The generic organism idea would also have been more convincing had there been a detailed discussion of potential critical receptors for the Canadian Shield area. These critical receptors would have been identified using screening criteria such as sensitivity and degree of potential exposure. Then, a cross-referencing with the PDFs could have been used to ensure that the PDFs were appropriate. [Comment 490, Source Document tec004, Page 176, Section E-2.1.5]

the selection of the non-human target organisms (R-Biosphere 1993: pp.366,17) does not reflect advances in current investigation and concepts about the wide range of responses that different organisms exhibit to ionizing radiation. [Comment 273, Source Document tec004, Page 232, Section H-2.3]

United Church of Canada

The use of environmental increments and four hypothetical generic organisms may be useful tools [AECL, 1994, p. 413-415] but their adequacy is unproved as a means to address the complexity of issues to which their use is suggested to apply or to provide the level of certainty necessary. [Comment 1745, Source Document phpub124, Page 3-21, Section 3]

OPG RESPONSE

At the time the work for the EIS was carried out, the data required for ecological risk assessment for

radiological contaminants had not been examined extensively. Pioneering work was carried out in calculation of dose conversion factors to permit estimation of doses to non-human biota and these are still in use (e.g. CEPA PSL2 Assessment, dated July 2001). Given the many uncertainties, conservative assumptions and criteria were used. The range of organisms and assumptions attempted to cover all types of organism.

A future site-specific ERA (see response to 4.06.03.01) would include surveys of potentially sensitive habitats, and identification of appropriate organisms and life stages, and use of the most appropriate data available. Some work has been done on identification of appropriate biota fo ruse in ongoing non-site-specific work (see response to 4.06.03.02).

Fish doses resulting from immersion in water and sediments are included in BIOTRAC (Davies et al. 1993, p. 372-373). Hence, fish are modelled as being exposed to groundshine.
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4.07.01 System Performance - Assessment Endpoints - Collective Dose and Risk

PARTICIPANT COMMENTS

Energy Probe (Rubin)

Even in the absence of any absolute non-zero standard or target, it is extremely important to calculate total population radiation dose, and total population health risks, in order to make important choices among alternative Concepts, technologies, sites, effort levels, and timing. [Comment 2072, Source Document phpub041, Page 13]

The Panel must, once again, direct AECL to model the collective dose or risk on the basis of total population. All the screenings, simulations, sensitivity analyses, design constraints, optimizations, etc., done with the SYVAC computer model must be redone, "on the basis of [both] total population and the individual". [Comment 2052, Source Document pub014r, Page 5]

Hare, Driedger, Jennekens, Rogers, and Shemilt

Among the subjects of concern are ... the apparent failure to calculate post-closure population doses [Comment 1408, Source Document phpub150, Page 4]

Health Canada

Although a detailed study of the critical group in the vicinity of a facility has been performed, there is little mention of the risk to populations. [Comment 924, Source Document gov006, Page 04]

International Institute of Concern for Public Health (Bertell)

The summary provided by Atomic Energy Control Limited (AECL) provides only a part of the information needed to calculate the number of cancer deaths and other health effects which will result from the radiation exposure of workers and the public during the pre- and post-operational periods.... This prevents calculation of the expected number of Person-Sievert exposure. Members of the general public at risk are treated in a similar incomplete way, with dose rate or dose estimates, and without the number of persons exposed. [Comment 2118, Source Document ph2tec002, Page 03]

Northumberland Environmental Protection (Fairlie)

The EIS and accompanying documents contain no discussion or calculation of collective doses.... there are three practical reasons for calculating such doses. First, the quantification of collective harm places the HLW in spent fuel into some perspective in terms of hazard. Second, collective doses from different nuclides allows the identification of the main nuclides of concern, and third, it permits comparisons of the radiological effects of possible measures (e.g. thicker containers) to mitigate the release of such nuclides. [Comment 1348, Source Document ph2tec006, Page 06]

AECL's EIS documents neglect consideration of collective doses, however its supplementary replies (dated May 17, 1996) ... calculate a regional collective dose rate of 4 x 10-4 person-Sv/a to the population of the southern part of the Canadian Shield. Why this area and population was chosen is not revealed.... since the key nuclides are globally distributed, global dose rates and doses need to be calculated as well. In particular, a graph showing global collective dose rates with time should be constructed for I-129, CI-36 if possible, and C-14 continuing out to 10 8 years, and showing the maximum collective dose rates. [Comment 1349, Source Document ph2tec006, Page 07]

Nuclear Awareness Project

[Describe] the expected human health impacts of a range of mishaps and accidents ... for the implementation stage of the vault and the post-decommissioning stage of the vault, including ... collective population doses for each scenario [Comment 1606, Source Document pub035, Page 4, Section B]

Saskatchewan Environmental Society

AECL only discussed maximum dose rates to individual atomic radiation workers. It makes no reference to the exposure of the total workforce to various forms of radiation. Nor does it discuss the projected health impacts from total workforce exposure... provide estimates of the total exposure of the workforce to various forms of ionizing radiation during the siting, construction, operation, decommissioning and closure of the proposed nuclear waste disposal facility.... estimate the resulting health consequences of this exposure. [Comment 1670, Source Document pub040, Page 07, Section 12]

Scientific Review Group

There is generally no attempt to estimate and assess the collective dose in person-sieverts, but rather only collective dose rate; accordingly the risks of fatal cancers and serious genetic defects to a population as a whole, arising from the preclosure phase, is not addressed [Comment 130, Source Document tec004, Page 151, Section D-2.2.7]

The SRG is concerned about AECL's reliance on the estimation of individual human dose. This reliance is apparently based upon the assumption that if the greatest individual risk is acceptable then the total risk to all persons exposed over all generations would also be acceptable. This assumption requires detailed justification. [Comment 184, Source Document tec004, Page 188, Section E-3.2]

The BIOTRAC model is concerned only with predicting the maximum reasonably possible dose; no specific attention is given to issues of sustained contamination of humans, perhaps in larger or more dispersed populations, by smaller doses over very extended periods. [Comment 271, Source Document tec004, Page 232, Section H-2.3]

OPG RESPONSE

The doses required to meet the CNSC risk criterion for the most exposed groups are very small (~1% natural background). Doses to less-exposed groups would be even smaller. Given the much higher levels of natural background, it is not clear if these doses have any significance. International groups have also stated that there is little basis for projection into the future, and collective dose is of limited use in demonstrating safety. However, future safety assessment should tconsider whether and how useful information could be provided.

Occupational collective dose during the preclosure phase was addressed in the EIS, and would be addressed in future as part of an ALARA assessment required for a construction license.

4.07.02 System Performance - Assessment Endpoints - Cumulative Effects PARTICIPANT COMMENTS

Energy Probe (Rubin)

AECL has avoided discussing ... the total inventory of persistent toxins which the planned waste repository is predicted to release into the environment.... It is that perverse attitude toward the release of large absolute quantities of persistent toxins that has led AECL to conclude (for example) that toxic releases into a lake would be better than release into groundwater-supplied wells. Moreover, AECL has again confused two separate issues: (1) Is the estimated harm acceptable? and (2) Could the estimated harm be statistically proven and linked to the cause? ... it is incumbent on this Panel to ensure that the natural environment and its non-human species are protected, beyond reasonable doubt, from significant total loadings of persistent toxins like 14C, 129I and 36C1. [Comment 2076, Source Document phpub041, Page 15]

Mouvement Vert - Mauricie

There is no mention of the cumulative impact. [Comment 1475, Source Document pub024, Page 09, Section 2.1.2]

Northwatch

the EIS does not consider accidents cumulatively, but only in terms of chances per year, rather than over 70 years of operation; [Comment 1381, Source Document pub046, Page 15, Section d]

Scientific Review Group

There is no explicit consideration of cumulative biosphere loading of contaminants and of their potential to induce significant environmental impacts.... 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 [Comment 140, Source Document tec004, Page 163, Section E-2.1.1]

OPG RESPONSE

The disposal system is designed to contain the radionuclides in used fuel for a very long time, allowing most of the radioactivity to decay away. Any eventual releases would be released slowly and would be delayed and absorbed further in the geosphere. Dilution in a water body in order to meet the individual risk criterion would not be an objective in siting or design.

It is planned to modify the biosphere model to calculate the (cumulative) concentration of radonuclides or other species of concern in water, soil and polants.

4.07.03 System Performance - Assessment Endpoints - Mental Well-Being

PARTICIPANT COMMENTS

National Action Committee on the Status of Women

The potential psychological health effects of the proposed concept are minimized and trivialized in the EIS. Although AECL includes mental well-being in its definition of health, it does not address potential mental health effects in any significant fashion. [Comment 1289, Source Document pub026, Page 30, Section 7.2.8]

The proponent should be required to perform a more serious analysis of what potential psychological impacts could be associated with implementation of the proposed concept under normal and accident conditions, paying specific attention to the implications for women in terms of domestic violence and women's mental health. [Comment 1290, Source Document pub026, Page 31, Section 7.2.8]

OPG RESPONSE

The applicable definition of health indeed included mental health. CEAA's EA requirements include only effects on health that are caused by a change in the biophysical environment. However, as a large employer and an undertaking causing potentially a significant change in the socio-economic conditions of the host community, it would be responsible of an implementing organisation to address this question. The technical program will estimate numbers of workers etc. to this end. Another factor is the psychological impact of living near a nuclear facility. Mitigation of this, e.g. by provision of information, would be the subject of negotiation during siting.

4.08 System Performance - Worse Cases

PARTICIPANT COMMENTS

Atomic Energy Control Board

Since the predicted impacts are still rapidly increasing at 10,000 years, R-104 requires that reasoned arguments be presented that the rate of discharge to the environment will not suddenly and dramatically increase and that an acute radiological risk will not occur (AECB, 1987a). One method of accomplishing this is to evaluate a bounding value of the maximum dose. However, the magnitude of the "global maximum" for 129I referred to in Section 6.5.2 (Postclosure PRD, p. 200) is not given. Also, the maximum doses from the other radionuclides in the nuclear fuel waste are not estimated.... The maximum release rate and maximum dose that SYVAC would calculate for all the contaminants is not presented. [Comment 585, Source Document gov002, Page 34, Section B.3.2]

The results and implications of not being able to comply with 500-year minimum [container] lifetime specification have not been evaluated. [Comment 2150, Source Document gov002, Page 44, Section C.1.3(i)]

Canadian Coalition for Ecology, Ethics and Religion

worst reasonable case modelling must be done

- a committee of independent experts could establish the criteria for the "worst reasonable case";

- the design lifetime specification is one reasonable, objective basis by which to set criteria for "worst reasonable case" modelling [Comment 1862, Source Document ph3pub160, Page 4]

The minimum design lifetime specification for the canister (presently set at 500 years) should be the time frame for which the environmental impact of total canister failure is evaluated, whatever the canister type and projected resistance to corrosion beyond that specification. The design lifetime specification is a reasonable, objective bases by which to set criteria for 'worst reasonable case' modelling. [Comment 1867, Source Document ph3pub160, Page 6]

Coalition pour la surveillance du nucléaire (COSUN)

The downplaying of negative impacts throughout the EIS has led AECL to the point where it will not even entertain the idea of worst-case scenarios ... The fact that "very unlikely situations" do occur does not seem to bother AECL at all. [Comment 1268, Source Document pub011, Page 05]

Concerned Citizens of Renfrew County

No details are given on the types or seriousness of possible accidents that could occur during all stages of the process. No consideration of worst-case scenarios is done [Comment 1964, Source Document pub031, Page 1]

National Action Committee on the Status of Women

the EIS does not consider the possible impacts of a major unpredicted accident or breach of the disposal vault [Comment 1281, Source Document pub026, Page 24, Section 7.2]

Natural Resources Canada

None of the sensitivity studies presented in this document describe cases where the waste disposal system failed to meet AECB dose guidelines. Although the sensitivity studies are extensive, they are not complete until the "limits of the envelope" are explored by varying the parameters until there is a significant probability of failure. Results of "crash test" scenarios with the limiting values of important parameters should be fully documented in a postclosure assessment study. [Comment 770, Source Document ph2gov001, Page pos2]

Northwatch

the EIS does not consider worst-case scenarios, such as the waste bypassing all the buffers after an accident [Comment 1382, Source Document pub046, Page 15, Section d]

Northwatch (Lloyd)

Deficiencies Which Emerged or Remain Outstanding After Discussion in the Phase II Tehncial Hearing Sessions ...

- worst case scenarios [Comment 1538, Source Document ph2tec045, Page 22]

Northwatch (Willis)

AECL's long-term analysis of the impact on human health looks at only 41 of the many radionuclides in the core of a reactor (see Appendix One): 14 fission fragments, 2 activation products, and 25 elements of the actinide decay chains.... A safety analysis of, for instance, a worst-case system failure, or a transportation accidents prior to closure, would need to consider a different and broader subset of the radioactive contaminants in the fuel. [Comment 1568, Source Document ph3pub096a, Page 10, Section 6]

Nuclear Awareness Project

[Describe] the expected human health impacts of a range of mishaps and accidents including the worst case scenario for the implementation stage of the vault and the post-decommissioning stage of the vault [Comment 1936, Source Document pub035, Page 4, Section B]

OECD/NEA Review Group

Compliance is judged by risk rather than by extreme consequences. This, however, does not mean that it is without interest to know the size of extreme consequences and the associated probabilities. [Comment 1224, Source Document tec001, Page 13, Section 4.2]

Saskatchewan Environmental Society

what kind of pressures will be placed on the containers when ... there is a major collapse of rock from a massive earth quake, which allows some sizeable fraction of a complete column of rock from the roof of the excavation to exert its full downward vector of pressure; Combined with this is a massive inflow of water along all the cracks between the blocks, which adds both hydrological pressure from the overall depth of the column of water as well as the lateral and vertical pressures of swelling clay. These are the really "conservative" situations, or "worst scenarios", around which AECL should have made all its computer and engineering calculations. [Comment 1698, Source Document ph2tec039, Page 7]

Scientific Review Group

a possible pathway for escaping radionuclides might lead from the buffer directly into an imperfectlysealed excavation-damaged zone, fractured rock web, or extension fracture, connecting to a highpermeability fracture zone in the rock, and from there to the surface environment. Transport along such a pathway would proceed substantially faster than would be predicted by the AECL vault model. [Comment 363, Source Document tec004, Page 050, Section 6.2.3]

AECL should have quantitatively investigated a scenario involving partial or complete failure of the waste exclusion zone in conjunction with other unfavourable but feasible events such as bypass of the backfill through the excavation-damaged zone and rock webs. The likelihood of such a scenario should have been expressed in probabilistic terms [Comment 385, Source Document tec004, Page 057, Section 6.3.1]

Extreme annual dose estimates (maxima) could also have been presented (along with standard deviations of the results). The public will be interested not only in average outcomes but in the extremes (however unlikely). The probabilistic analysis has been limited almost entirely to a parameter sensitivity study. The alternative uses (such as showing overall output probability distributions and extreme outcomes) might have been more interesting and useful. [Comment 169, Source Document tec004, Page 184, Section E-3.1]

The public will be primarily interested in improbable, but high-consequence outcomes. Therefore, in addition to the median-value and arithmetic mean presentations, some treatment of worse case scenarios would have been appropriate.... the real issue is the probability of extreme doses. [Comment 191, Source Document tec004, Page 189, Section E-4]

Presentation of probabilistic simulations using arithmetic averages, while complying with AECB regulations, is not adequate because it does not allow a full appreciation of the variability involved in the results and does not present extreme annual dose estimates (which are of great interest to the public even though the probabilities of such extremes are very low). [Comment 203, Source Document tec004, Page 191, Section E-5]

The robustness of the concept needs to be demonstrated in terms of its ability to accommodate a wide range of scenarios. The EIS and new case studies may give the impression that AECL has looked at a wide range of scenarios and therefore has addressed the concerns expressed in the SRG Report. However, the types of scenarios required for concept development include situations such as extreme lifestyle habits in terms of diet, transitional processes, and the bioaccumulation of radionuclides in food (plant, fish). [Comment 527, Source Document tec004a, Page 12, Section 2.6]

OPG RESPONSE

As noted elsewhere in these responses (e.g. 7.03.13.02), future safety assessment will include an explicit treatment of a number of "what if" scenarios that test the robustness of the concept to various assumptions. Ideally, there will be an opportunity for defining these scenarios with the stakeholders (e.g. regulators, local community) during the safety assessment process, rather than waiting for the final report to see if the results of interest are included. One class of cases of interest is the failure of barriers. However, it may only be possible to provide qualitative estimates of probabilities for these worst-case scenarios.

Some of the comments relate to considering the case of failure at the design lifetime of the container, or 500 years (#1,#2, #3,#4). It should be noted that the EIS study considered a range of failure times starting at vault closure, based on a combination of fabrication defects and a corrosion rate model; the SCS considered any failed canisters to occur immediately at vault closure.

One comment (#11) noted an interest in whether other nuclides would be more important in other scenarios. This was certainly acknowledged in the EIS, where the nuclides of most importance for human intrusion scenarios were different from those for failed canister and groundwater transport scenarios. The development of the Radionuclide Screening Model (RSM) and its related 400+ nuclide database is intended, in part, to provide a more comprehensive answer to such questions (i.e., which nuclides need to be considered?) (Goodwin et al. 2001; Garisto 2002).

References:

Goodwin, B. et al. 2001. Radionuclide Screening Model (RSM) Version 1.1 - Theory. OPG Report 06819-REP-01200-10045 R0.

Garisto, F. 2002. Radionuclide and element specific data for the Radionuclide Screening Model Version 1.1. OPG Report 06819-REP-01200-10038-R01.

4.09 System Performance - Spatial and Temporal Boundaries

PARTICIPANT COMMENTS

Canadian Coalition for Ecology, Ethics and Religion

[could] the vault as proposed ... meet the radiation protection standard with compliance assessed for the time when the peak risk occurs, whenever that may be. [Comment 1842, Source Document phpub043, Page 35, Section 13]

Durham Wetlands and Watersheds

Planning for the EIS should have been for timespans of 100 000 or even 1 000 000 years as opposed to 10 000 years. [Comment 2002, Source Document pub043, Page 5]

Energy Probe (Rubin)

The Panel should recommend that the Concept, and any future planned repository, be shown to meet the Panel's criteria for safety and acceptability for as long as the wastes remain hazardous and certainly for as long as we expect hazardous releases to increase. [Comment 2080, Source Document ph2tec024, Page 2]

The June 1988 publication ACNS-11, Principles and Guidelines for Radioactive Waste Disposal Facilities, ... includes the following thoughtful suggestions, not one of which has been implemented by AECL in the EIS: For widely-dispersed, and in some cases longer-lived, wastes (e.g., H-3, C-14, Kr-85, I-129), the integration limits for evaluating collective risk commitments should, in principle, encompass the Earth's surface and extend for a time that is long in comparison to the half-lives of the waste products. [Comment 2073, Source Document phpub041, Page 13]

International Institute of Concern for Public Health (Bertell)

It is also not clear over how many years the post-closure risk continues. [Comment 2117, Source Document ph2tec002, Page 03]

Northumberland Environmental Protection (Fairlie)

For each nuclide, dose/time graphs should be presented showing the expected mean doses to the critical group over 100,000,000 years. [Comment 1935, Source Document ph2tec006, Page 3]

United Church of Canada

The Concept must demonstrate protection for as long as there is radioactivity that could irradiate or contaminate groundwater. [Comment 1735, Source Document phpub124, Page 3-14, Section 3]

OPG RESPONSE

OPG's safety assessment looks at the time of peak risk (rather than limiting assessment to 10 000 years). However, increasing uncertainty with time is recognised, and a suite of performance measures may be appropriate.

The spatial extent of radionuclide distribution should also be looked at, as described in other responses.

5 SITING

5.01 Siting - Criteria

5.01.01 Siting - Criteria - Identification and Ranking

PARTICIPANT COMMENTS

Atomic Energy Control Board

The EIS does not provide sufficient insight into what makes a site technically good or bad. The EIS recycles some general site criteria originally specified in R-72 (AECB, 1987b), but does not translate these general criteria into more specific recommendations. [Comment 555, Source Document gov002, Page 06, Section 5]

AECB staff expected the EIS to highlight features or characteristics of a site which were desirable and undesirable either generally or in the context of specific repository design choices. This is needed so that a site which might be offered from a non-technical perspective (e.g., a community volunteering a site) could fairly quickly be screened to see if more detailed work could be justified. [Comment 556, Source Document gov002, Page 07, Section 5]

Any future proponent should be encouraged to quickly develop a site selection and screening process which focuses both on technical and social factors, and how they interrelate, as well as on site screening and rejection mechanisms which could be used during early stages of the siting process. [Comment 557, Source Document gov002, Page 07, Section 5]

Favourable and unfavourable site characteristics are not identified based on the parameters that are predicted by the postclosure performance assessment to be important to the safety of the facility, or on the assumptions and limitations of the postclosure performance assessment.... The postclosure assessment employs a large number of assumptions and limitations. These modelling constraints are not evaluated to identify favourable or unfavourable site characteristics. [Comment 692, Source Document gov002, Page 79, Section E.3.1]

Key factors in the reference design cannot be evaluated until late in the site characterization program, such as the nature and extent of fracturing and the in-situ stress field at the repository horizon. AECL does not attempt to identify measurable indicator conditions for those desirable and undesirable characteristics that can only be quantified later in the site characterization program. [Comment 694, Source Document gov002, Page 80, Section E.3.1]

The EIS does not identify the limits of acceptable and unacceptable properties for the rock block, the bounding features or the surface environment. [Comment 695, Source Document gov002, Page 80, Section E.3.2]

Acceptance criteria identify the states or values of important site characteristics that will enhance safety. Rejection criteria identify the limits on site characteristics that cannot be tolerated, no matter what compensating conditions may exist. There is little discussion of such criteria for the rejection of unsuitable regions, the rejection of unsuitable sites, the ranking of suitable sites and the selection of a site for development. Nor are there criteria presented for site abandonment during underground characterization. [Comment 696, Source Document gov002, Page 80, Section E.3.2]

there appears to be no mechanism for rejecting a site if it proves inadequate. [Comment 700, Source Document gov002, Page 81, Section E.3.3]

Canadian Geoscience Council

it is crucial not to make geological exclusion decisions on unreliable information and, by mistake, exclude sites that would turn out to be eminently acceptable. [Comment 1039, Source Document tec002, Page 15, Section 3.2.1]

There is little discussion of proposed responses to the unexpected, and there is little discussion of procedures for making negative decisions--site exclusions-when an area has been substantially investigated. It is well known that it is difficult to close down an option in which a lot of money and time have been invested. [Comment 1043, Source Document tec002, Page 16, Section 3.2.2]

Energy Probe (Rubin)

What minimum "performance criteria" -- and how many -- are appropriate for the decision to bury highlevel nuclear waste? What levels for these criteria does AECL propose? To what extent should deterministic ("pass-fail", "disqualifying", or "drop-dead") criteria be applied in the process of site screening or selection? Which such criteria does AECL propose using? [Comment 2056, Source Document pub014r, Page 6]

Hare, Driedger, Jennekens, Rogers, and Shemilt

Among the subjects of concern are ... the need for AECL to specify site-selection criteria [Comment 1406, Source Document phpub150, Page 4]

Inter-Church Uranium Committee (Fortugno)

at the concept proposal stage AECL refuses to provide clear and detailed ... exclusionary criteria. [Comment 2102, Source Document ph2pub031, Page 5, Section IV]

McMaster Institute for Energy Studies

the public and potential host communities should have input into or at least be privy to the decisionmaking process used in the formulation of the exclusion criteria. [Comment 1427, Source Document phpub033, Page 03]

Exclusion criteria based on ethical, social, cultural, aboriginal, and archaeological issues are not sufficiently considered. [Comment 1428, Source Document phpub033, Page 03]

Northwatch

the preferred land uses identified in the EIS are very limited; the EIS should provide some rationale or criteria for identifying or citing the preferred land uses and provide some rationale for the exclusion of recreation, wild areas retention, mining, etc. from list of preferred land uses [Comment 1369, Source Document pub046, Page 14, Section d]

the EIS should state exclusion criteria, rather than referring development of exclusion criteria to an unidentified "implementing organization" (5.1.3); exclusion criteria are an essential component of the concept, and should not be deferred to a later stage [Comment 1389, Source Document pub046, Page 18, Section d]

the EIS should contain a discussion of failure, and alternatives following failure [Comment 1396, Source Document pub046, Page 20, Section d]

Northwatch (Lloyd)

Deficiencies Which Emerged or Remain Outstanding After Discussion in the Phase II Tehncial Hearing Sessions

-absense of exclusion criteria [Comment 1532, Source Document ph2tec045, Page 22]

Deficiencies Which Emerged or Remain Outstanding After Discussion in the Phase II Tehncial Hearing Sessions ...

- criteria for repository abandonment [Comment 1537, Source Document ph2tec045, Page 22]

Additional Key Information Deficiencies Identified in Phase II Technical Hearings (June 1996) ... - definition/determination of "remoteness", and relevance to siting criteria [Comment 1549, Source Document ph2tec045, Page 24]

Northwatch (Richardson)

Siting criteria should be established prior to any sieving process, in order to parallel volunteer siting programs overseas. [Comment 1526, Source Document ph2pub009, Page 17, Section 6]

Northwatch and Campaign for Nuclear Phaseout (Kreusch, Neumann, and Gruppe Ekologie)

criteria must be formulated as specifically as possible, as early as possible, in order to be subject to proper scientific and public debate. "Criteria" in this context of site selection means rules which are formulated as a basis for deciding between different alternatives (sites) as well as cut-off or knock-out criteria (to decide whether to include or exclude sites during screening). They are heavily dependent on local and regional conditions and cannot be formulated for universal application. [Comment 1594, Source Document ph2tec044, Page 19, Section 6]

OECD/NEA Review Group

We believe that it would provide the greatest flexibility in site choice and would maximise the potential of the voluntarism approach if the siting territories were not to be prescribed too closely at the outset. [Comment 1240, Source Document tec001, Page 16, Section 5.1]

The qualitative listing of favourable attributes advanced by AECL is at an adequate level for the initial stages of siting. Prescriptive guidelines or criteria which are couched in too quantitative terms may be unhelpful since suitability depends not just on the siting characteristics, but upon the integrated system behaviour. [Comment 1242, Source Document tec001, Page 16, Section 5.1]

Robertson, J.A.L.

a distinction should be made between absolute and desirable criteria. While absolute criteria, e.g., mineral exploitation or sacred aboriginal sites, should be used to exclude potential sites, desirable criteria, e.g., the presence of locally scarce species, should be used to select between sites. [Comment 1459, Source Document phpub004, Page 33]

Scientific Review Group

AECL has presented a comprehensive list of geotechnical criteria ... the criteria are not ranked for the process of candidate site selection or rejection in the screening process; [Comment 323, Source Document tec004, Page 015, Section ES]

The document does not indicate how either qualitative or quantitative and defensible criteria for siting a nuclear fuel waste disposal facility will be developed and ranked to determine which sites can be disregarded and which sites merit further evaluation... "...the AECB ... has established ... qualitative guidelines that pertain to geotechnical conditions for a disposal vault site:..." These general qualitative AECB guidelines should form the basis for the development of more specific qualitative and quantitative criteria for screening and evaluating potential nuclear fuel waste disposal sites.... the siting technology methodology presented in this document does not reflect how changes in criteria, or ranking of criteria, would be accommodated in the siting process. [Comment 2, Source Document tec004, Page 105, Section A-2.1.1]

A principal objective of site screening must be to determine those characteristics of the geological setting of any candidate site that would promote containment of radionuclide and other contaminants, and hence isolation of nuclear fuel waste from the surface, and to develop criteria to rank those characteristics. [Comment 3, Source Document tec004, Page 105, Section A-2.1.1]

Very few of the features of the surface and subsurface biosphere components, that could be important in preclosure and postclosure assessment of the disposal facility are mentioned (R-Siting 1994: p.56f). The document does not show how critical features would be identified and combined and ranked with geotechnical criteria. [Comment 5, Source Document tec004, Page 106, Section A-2.1.3]

Those attributes of the geosphere that control its effectiveness as a barrier must be included in the site screening and the site evaluation processes. Accordingly, it is necessary to establish and specify site evaluation exclusion criteria concerning those properties of the geosphere that control its effectiveness [Comment 548, Source Document tec004a, Page 20, Section 4]

OPG RESPONSE

Technical siting criteria must be developed and approved as part of each significant step in the siting process: from preliminary screening of siting regions, to comparative evaluations between candidate areas, and to between candidate sites within these areas. For example, broad exclusion criteria can first be developed to address such unfavourable geotechnical factors such as moderate to high seismic hazard, abnormal ground water chemistry, presence of

valuable natural resources, poor bedrock exposure or outcropping, geologic structure is highly heterogeneous/complex, moderate to high local topographic relief and high density of faults and fracture zones. These criteria would be further expanded to include social and economic factors, as appropriate.

As the screening process proceeds into specific large siting regions, exclusion criteria would be developed to include concerns of each potential host community. As candidate areas within the siting regions are identified, comparative ranking criteria including detailed technical factors would have to be available to guide the characterisation and evaluation process. It is likely that some of the comparative criteria would be performance based, such as pre- and post-closure levels of risk to critical groups, and require the input of site-specific characteristics into assessment models. As such, no single characteristic would necessarily be compared between candidate areas or sites, but rather the performance of each system or sub-systems would form the basis for comparison.

As the understanding of factors critical to groundwater flow and contaminant transport in deep geologic environments continues to be refined, it can be anticipated that new suitability criteria will be developed or existing criteria modified. For example, a better appreciation of the effects of density gradients (i.e. variably saline fluids) on the stability of deep groundwater flow systems may lead to the development of refined repository siting criteria. In 2001, OPG

began undertaking numerical studies to clarify the physical and geochemical properties that are important in determining regional groundwater flow patterns and evolution in the fractured crystalline setting of the Canadian Shield (Gierszewski et al. 2001, Sykes et al. 2003).

The organization responsible for the siting of an deep geologic repository would likely establish a stakeholder review procedure at key milestones in the siting process. The purpose of such reviews would be to examine results to date and to ensure that appropriate selection decisions are made as to whether candidate sites remain included in the siting process or not. A key objective of such a siting process would be to identify candidate repository sites that are technically, socially and economically viable. It is not required that the siting process identify the best site(s).

References:

Gierszewski, P., S.B. Russell, F. Garisto, M.R. Jensen, T.F. Kempe, P. Maak and G.R. Simmons. 2001. Deep geologic repository technology program - annual report 2000. Ontario Power Generation Report 06819-REP-01200-10055-R00.

Sykes, J.F., E. Sudicky, M. Jensen, S. Normani and R. McLaren. 2003. Strategy to assess regionalscale flow and transport from a used nuclear fuel repository in fractured crystalline rock. Geological Society of America Annual Meeting, Denver, USA.

5.01.02 Siting - Criteria - Recommendations

PARTICIPANT COMMENTS

Atomic Energy Control Board

The rock properties and in situ conditions needed to ensure the long-term integrity of the exclusion zone should be specified as a siting constraint. This was not done, and it is not clear that the modelling is capable of deriving such constraints. [Comment 580, Source Document gov002, Page 30, Section B.2.2(iii)]

These criteria should include consideration of the potential for site improvements or modifications, such as grouting and pre-grouting, which are neither assessed nor discussed in the documents. [Comment 916, Source Document gov002, Page 80, Section E.3.2]

Examples of siting criteria that could have been derived but were not include: (i) acceptable or unacceptable limits of the extent of postglacial faulting ... (ii) the minimum distance from existing mine or mine workings ... (iii) limits on the acceptable or unacceptable mineralization or other natural resources that may occur on a site ... (iv) the minimum spacing of major structural features and minimum size of the host block of rock ... (v) limits of acceptable topography` ... (vi) acceptable or unacceptable limits on the degree of fracturing of host block of rock (and the waste exclusion zone in particular) and on the geomechanical properties of the host rock; and (vii) limits on the magnitude and anisotropy of the in situ stress ... [Comment 697, Source Document gov002, Page 81, Section E.3.2]

Campaign for Nuclear Phaseout

The presence of mineral deposits at a proposed site increases the risk that future underground prospecting might breach repository walls. What legislative measures, design and long-term criteria are proposed to deal with such a possibility? Has proximity of mineral deposits been included as a potential risk factor in the siting of a repository? [Comment 1788, Source Document pub027, Page 23, Section III.C]

Canadian Geoscience Council

The recent discovery of kimberlite deposits of economic value into the Canadian Shield was not mentioned and needs to be considered as an exclusion criterion. [Comment 1034, Source Document tec002, Page 13, Section 3.1.2]

It appears to us that applying the exclusion criteria to some of the driest, most stable, abandoned mine sites may provide an alternative for both geological and economic considerations.... the concepts of Waste Exclusion Distance (WED) and Excavation Damage Zone (EDZ) are well defined in the proposed concept, and mined areas could be scrutinized within this context. [Comment 1035, Source Document tec002, Page 14, Section 3.1.2]

The EIS implies that the search will be limited to Archean areas of the shield, which is reasonable, but may be unnecessarily restrictive. There may be geologically suitable sites in Grenville and other Canadian Shield geologic provinces. [Comment 1036, Source Document tec002, Page 14, Section 3.1.2]

The final exclusion criteria should be as general as possible, and should consist of a list of properties desired and properties to be avoided that is independent of specific nomenclature.... Thus, we advocate an expansive view of the concept of disposal in plutonic rocks of the Canadian Shield: our recommended version is "homogeneous, massive, tectonically stable" rocks in the geosphere. [Comment 1037, Source Document tec002, Page 15, Section 3.1.3]

There should be full scale examination of fault and fracture zones by experts who are skilled in the difficulties of detecting movements, and this should be done early in the site screening process so that criteria can be developed for determination of motion along fractures. [Comment 1049, Source Document tec002, Page 18, Section 3.3.2]

The site selection criteria will presumably demand a site for the repository in an area with few faults and fractures. While this is common sense, it has not yet been demonstrated that there are any plutons in Canada that are not fractured and faulted at the scale of the repository--the emplacement mechanisms, cooling histories, and long tectonic history almost ensure that fractures will be present. Moreover, the act of mining itself on this scale will create stresses that may reactivate faults and fractures, as has been seen at several experimental sites world wide. [Comment 1051, Source Document tec002, Page 18, Section 3.4.2]

Durham Wetlands and Watersheds

The Nuclear Fuel Waste Facility must not be located near a known or future population centre. [Comment 2004, Source Document pub043, Page 5]

Environment Canada

There is a need to set up a clear list of qualifying and disqualifying criteria for site acceptability with respect to the volume of rock needed, the spacing of large structural discontinuities, the permeability of the sparsely fractured rock between discontinuities, etc.... A waste exclusion distance should be included in a list of qualifying and disqualifying criteria for site acceptability [Comment 833, Source Document gov003, Page 08, Section 2.1]

Inverhuron and District Ratepayers Association

We are pleased to offer wholehearted support for a DISPOSAL PLAN for nuclear wastes away from 1) tourist concentrations 2) agricultural areas 3) towns and villages 4) the Great Lakes fisheries and water system; AND, away from the already concentrated risk represented by the operation and presence of the Bruce reactors themselves. [Comment 2125, Source Document ph3pub178, Page 1]

Joint Committee of the Canadian Academy of Engineering and the Royal Society of Canada

During site selection, there should be full examination of fault and fracture zones for evidence of recent movements and of recent sedimentary deposits for evidence of past seismicity. [Comment 1162, Source Document ph2tec007, Page 08]

McMaster Institute for Energy Studies

there is scant attention paid to the concept and importance of endangered species and the preservation of their habitats.... This leaves the impression that valued environmental components would be "managed", "avoided" or "protected" rather than excluded from consideration as a site.... The habitats of many endangered species may be specific to a local region; however, they are clearly recognized by the provincial government and easily located and as such should constitute a significant element in the preliminary exclusion criteria. [Comment 1440, Source Document phpub033, Page 16]

Natural Resources Canada

Possibly a batholith would be as suitable as a pluton for a disposal site, although detailed studies tend to show that the boundaries of individual plutons are major mechanical discontinuities. [Comment 743, Source Document ph2gov001, Page sit4]

Northwatch and Campaign for Nuclear Phaseout (Kreusch, Neumann, and Gruppe Ekologie)

Prediction of the long term behaviour/reliability of engineered barriers cannot be predicted with certainty. To guarantee long term safety it is necessary to have a very good geological barrier. [Comment 1586, Source Document ph2tec044, Page 16, Section 5]

OECD/NEA Review Group

It is not essential, or even possible to locate the 'best' site. The sparsely fractured rock (SFR) found at the URL is clearly very useful in building a safety case, but provides high margins of safety and finding it elsewhere is not essential. [Comment 1248, Source Document tec001, Page 17, Section 5.1]

Scientific Review Group

The characteristics of the various types of plutonic rocks in the Canadian Shield are not adequately elaborated upon and there is little indication how the variation of these characteristics will be addressed during site screening and evaluation... Different granite plutons have distinct tectonic histories (pre-, syn- and post-tectonic), emplacement depths and cooling rates, and accordingly may vary widely in fracture intensity, and residual stress.... These differences are only noted in qualitative terms (R-Siting 1994: p.35, p.49).... Post-tectonic plutons that are intruded after most of the pervasive deformation in the rock mass has ended generally may be much better candidates for a disposal vault than those that have been deformed. Post-tectonic plutons can readily be identified on the basis of the conjunction of available reconnaissance geological mapping, composition, geochronology, and published information on regional tectonic evolution [Comment 15, Source Document tec004, Page 108, Section A-2.1.5]

It is important to specify a minimum required exposed bedrock such as 1%, 5%, etc. as well as the distribution of outcrops in the candidate area. [Comment 910, Source Document tec004, Page 109, Section A-2.1.6]

There is no consideration given to flow system dynamics as a safety factor. The document states that an objective in vault placement will be to maximize the overall distance the contaminant will have to travel (R-Siting 1994: p.60).... It would seem more important to maximize travel time than travel distance [Comment 481, Source Document tec004, Page 111, Section A-2.2.1]

There is no consideration given to the potential safety feature of groundwater density in the site evaluation model. Groundwater density can influence groundwater flow.... there is isotopic evidence that saline groundwaters are much older than less saline, near-surface counterparts ... This information could be used to map the residence times of groundwater through the Canadian Shield and therefore could be a powerful siting tool in the future. There is no focused effort to determine a quantitative relationship between groundwater density and residence or travel time in the context of the siting study. Although the model MOTIF has the capability to handle density-dependent flow and transport modelling, it has yet to be used in that role.... There is no indication as to how saline groundwater conditions are, or will be, included in site screening and evaluation methods; or how this crucial characteristic could be used in demonstrating disposal vault safety. [Comment 482, Source Document tec004, Page 111, Section A-2.2.1]

OPG RESPONSE

The EIS presented a series of technical factors that were considered important in any future repository site screening process. These broad technical factors can be used to form the framework of a selection process for the purpose of identifying siting regions, and subsequently potential candidate areas, within the Canadian Shield. These broad technical factors included a mixture of acceptance and exclusion criteria such as seismic hazard zones 0 or 1, no evidence of postglacial faulting, no known current or likely future valuable mineral resources, absence or low density of major lineaments indicative of subsurface faults and fracture zones, presence of low local topographic relief indicative of slower groundwater flow paths and the presence of surface areas with low environmental sensitivity

and value. This approach is consistent with that followed, for example, in the Scandinavian used fuel waste management program.

The Nuclear Waste Management Organization responsible for implementing the siting process could use these broad technical factors as part of the formulation of exclusion and acceptance criteria appropriate for the various stages of the selection process. For example, within specific regions or candidate areas in the Canadian Shield, specific groundwater chemistries and fracture infilling mineralogies could be indicative of long groundwater residence times and long-term flow system stability. The development of final repository designs would also result in application of more specific siting criteria based on rock properties and in-situ stress fields that could influence repository stability and required design. The concerns of potential host communities would also have to be translated into siting criteria prior to initiating the identification of potential candidate areas for more detailed investigations. Ultimately, the application of deterministic criteria based on site-specific characteristics of the surface and subsurface environments could be enhanced by the results of system-wide performance assessments that take into account the interaction of the various components of a potential repository environment.

In response to comments, the OPG work program has in part been direct toward improving the geoscientific basis for the Deep Geologic Repository concept. A major aim of this work is to foster the development of methodologies and tools that illustrate issues of geologic and hydrogeologic stability in a fractured Shield setting. This includes 3-dimensional analyses of regional and repository scale groundwater flow systems to demonstrate the effect of topographic and density gradients, permeability distributions and spatial correlation, fracture network geometry and transient boundary conditions on flow system evolution (i.e. groundwater residence times). This work coupled with paleohydrogeologic, hydrogeochemical, isotopic and modeling case studies purposely designed to illustrate the robustness of flow system predictions resulting from site characterisation uncertainty provide a means to discuss and communicate the suitability of Shield settings. This approach also contributes to an improved understanding and consensus on the relative influence of site-specific geological, hydrogeological and geomechanical features to long-term repository performance (e.g. groundwater salinity). As such, it will provide a reasoned basis to discuss geoscientific aspects of repository safety and aid in the derivation of siting criteria to assess site-specific suitability.

5.02 Siting - Characterization Approach

PARTICIPANT COMMENTS

Atomic Energy Control Board

The EIS ... does not adequately identify the information and data needs for the various stages of the siting process. [Comment 679, Source Document gov002, Page 76, Section E.1]

The EIS does not identify what regional-scale information will be needed for site screening [Comment 680, Source Document gov002, Page 77, Section E.1.1]

The requirements for characterizing the fault or fracture zones that bound the block of rock hosting the repository are not adequately discussed. [Comment 683, Source Document gov002, Page 77, Section E.1.2]

the logic and methods of integrating the disparate regional-scale and site-scale survey techniques and how the results would be used to reach decisions about the technical acceptability of a site are not presented. [Comment 688, Source Document gov002, Page 78, Section E.2]

The procedures, processes and mechanisms to integrate the data are not adequately discussed.... Discussions on the interpretation and integration of data obtained by different geophysical methods is missing. [Comment 689, Source Document gov002, Page 78, Section E.2.1]

The description of the site characterization technology, the logic and methods of integrating the disparate survey techniques and how the results would be used to reach decisions about the technical acceptability of a site are not discussed in the context of a decision-making process for siting a repository. [Comment 698, Source Document gov002, Page 81, Section E.3.3]

The transition from a region to a site is a crucial point in the site selection process, but the EIS does not describe this decision-making process clearly. [Comment 699, Source Document gov002, Page 81, Section E.3.3]

Canadian Geoscience Council

we see long lists of studies that will be done in siting a repository, but we are provided with little clear information on how they will influence the selection process, or how they will be incorporated into the models. The point of this discussion is that we strongly recommend a more integrative and interdisciplinary framework for both the site selection and the modeling. [Comment 1030, Source Document tec002, Page 09, Section 2.1.3]

it may be better to keep geological sites available and under scrutiny as long as possible in parallel while the other criteria are being vetted on specific sites. This will not be an economically popular strategy because of cost, but a reading of Nuclear Imperatives(Carter 1987) or (NRC 1990)shows the delays and costly tragedies that occur when a final site is found to be unworkable. [Comment 1040, Source Document tec002, Page 15, Section 3.2.1]

an intermediate step of combining ground geophysics, a few drill holes and detailed surface mapping should be inserted before the grid stage to gain a good grasp of the 3-D geometry of a significant portion of the pluton. By this intermediate technique, possible vault locations for doing grid work are selected, and (2) problem spots like fracture zone junctions, etc. are selected for grid area or special work. [Comment 1042, Source Document tec002, Page 16, Section 3.2.2]

One modification of the proposed site-selection strategy that may save time and money is to place a high priority on determining the three-dimensional properties at a fairly large scale. [Comment 1045, Source Document tec002, Page 16, Section 3.2.3]

Discussion should be started immediately between those charged with burial responsibilities and the GSC and Provincial Geological Surveys to begin field work to: check areas for reliable and consistent data bases; ground truth for remote sensing; and mapping of areas where the geologic coverage is inadequate for the screening and exclusion decisions. The rapid implementation of this is particularly important given current Federal and Provincial budget cutting decisions that are eroding the good-quality mapping capability that Canada has developed over the past decades. [Comment 1046, Source Document tec002, Page 17, Section 3.2.3]

Geological and geophysical studies of the nature and configuration of the major and minor geological formations of the area and of the open fracture systems they contain are needed. [Comment 1073, Source Document tec002, Page 28, Section 5.1]

Studies of the effect of different kinds of complications should be included in the in conceptual models, for example, studies of tidal water pressure changes vs how the site hydrological model predicts them or studies of how well the site model predicts water migration due to mining and backfilling operations. Studies of borehole temperatures and natural heat flow can provide tests of the site model predictions. [Comment 1075, Source Document tec002, Page 28, Section 5.1]

that evaluation must be done in three-dimensions because the repository for the waste and the buffering effect of the geosphere will only be as secure as its weakest dimension. [Comment 1018, Source Document tec002, Page ii, Section ES]

Environment Canada

What is needed is a strategy to minimize the cost of site characterization by identifying the existence of the permeable fracture zones. Emphasis should be placed on locating these features rather than characterizing them. [Comment 834, Source Document gov003, Page 09, Section 2.2]

Joint Committee of the Canadian Academy of Engineering and the Royal Society of Canada

We concur with the CGC Committee in their emphasis on combining 3-d geophysics with detailed surface mapping and several drill holes in order to evaluate the 3-d geometry of a region before searching for a vault location by grid methods (Ref. 15, p.16). We support the general strategy for site selection outlined by AECL and would emphasize the importance of including groundwater geochemistry to indicate regions where there may have been little water circulation in the past thousands to millions of years, choosing a recharge area, including 3-d ground geophysical investigations at an early stage in the evaluation process to select a region which is relatively homogeneous in the third dimension, and obtaining expert evaluation of fault zones to exclude regions where there have been recent fault movements. [Comment 1164, Source Document ph2tec007, Page 10]

Natural Resources Canada

No discussion was found on the integration or modelling of all data sets for the purpose of providing an objective site evaluation.... it would be necessary to develop 3D modelling capabilities in order to handle some of the data sets used in nuclear waste disposal siting; borehole geophysics for example. [Comment 741, Source Document ph2gov001, Page sit3]

There is no mention of how the small grid areas for detailed study would be selected within the candidate area.... a discussion of the rationale used to select the grid areas would be useful. [Comment 751, Source Document ph2gov001, Page sit6]

outstanding requirements relate to the need for data interpolation and integration that may be used to go from scattered measurements to a final quantitative model of hydrodynamic properties at the site. For instance, there is no mention of geostatistical methods, although these are widely used in aquifer and petroleum reservoir characterization. [Comment 818, Source Document ph2gov001a, Page 17, Section 2.5.2]

Northwatch (Richardson)

There is currently no clear indication how AECL propose to compare safety assessments at several sites, and select the most promising for final underground characterisation. [Comment 1512, Source Document ph2pub009, Page 05, Section 2]

there is little discussion of the iterative nature of the development of the site-specific conceptual models erected, and how results from various stages of the exercise related to the final version of the model. [Comment 1518, Source Document ph2pub009, Page 09, Section 2]

AECL's proposals, while incorporating some aspects of international practice, are not sufficient to ensure that adequate intercomparison of potentially suitable sites is undertaken. Cost is not the factor by which safety should be measured.... specify more rigidly the number of areas and sites which must be characterised in order to enable adequate intercomparison. [Comment 1527, Source Document ph2pub009, Page 17, Section 6]

Northwatch and Campaign for Nuclear Phaseout (Kreusch, Neumann, and Gruppe Ekologie)

develop ... a comprehensive procedure for identifying suitable repository locations, and for proving their actual suitability, which takes into account both the specialist expectations of such a procedure, and the demand for information the public [Comment 1592, Source Document ph2tec044, Page 19, Section 6]

OECD/NEA Review Group

As part of the siting process it would be beneficial if the petrological and tectonic factors controlling the genesis and distribution of sparsely fractured rock within the Shield could be established more clearly. More specific discussion of the advantages of being in a 'tectonic shadow' and less simplified comparisons with the Scandinavian Shield would enhance the discussion. [Comment 1212, Source Document tec001, Page 10, Section 3.2.1]

further development of a geochemical (rather than largely hydrogeological) approach to repository siting is encouraged. For example, the controls on groundwater redox conditions and salinity need further evaluation in order to establish better mechanistic models, understanding of which may then affect the siting programme. [Comment 1216, Source Document tec001, Page 10, Section 3.2.2]

The Group considered that methodologies for narrowing down from areas to these candidate sites should be thought out at an early stage, and should not be too lengthy or involve overly detailed studies. [Comment 1244, Source Document tec001, Page 16, Section 5.1]

Site characterisation studies need to be broad based and put emphasis on both structural and hydrogeological investigations defining present-day conditions and on characterising the long-term chemical stability of the system, particularly in the near-field region, using hydrochemical and neotectonic studies of site stability. [Comment 1245, Source Document tec001, Page 16, Section 5.1]

Scientific Review Group

in most parts of the Canadian Shield, for geological mapping at a scale of 1:16000 (R-Siting 1994: Table 6.1 p.126), every outcrop should be examined in detail, not just those along the grid lines. Special efforts should be made to trace out in detail the surface trace of faults, major fractures and contacts between different rock types. Geophysical grid surveys should be completed before the final stages of the geological mapping so that the geophysical data can be used to guide the final stages of the geological mapping (R-Siting 1994: p.7-8).... The document does not clearly described how smaller study areas would be selected, and therefore, how the characteristics of the large areas could be inferred from information obtained from these smaller areas. [Comment 512, Source Document tec004, Page 109, Section A-2.1.6]

AECL does not at present have a clear strategy of how to collect information in a manner that would be both cost-effective and translatable into flow and transport model parameters. AECL does not seem to possess a sampling strategy that would help optimize the reliability of its model input data. There is a need to articulate a more systematic approach to the design of sampling and measurement networks, with optimized cost efficiency for translating data into model input parameters for a groundwater flow regime, and assessing quantitatively the reliability of these model inputs. [Comment 26, Source Document tec004, Page 115, Section A-3]

OPG RESPONSE

The various stages involved in site characterization are directly linked to the development of a conceptual model of the subsurface. At the preliminary candidate area stage, activities such as surface geophysical surveys, detailed field mapping studies and lineament analysis are initially integrated to form the preliminary conceptual site model. Based on this model, several small areas may be identified that warrant more detailed study for the purpose of testing conceptual model validity and establishing the scale of subsurface heterogeneity. Borehole drilling, core logging, downhole geophysical surveys, hydraulic flow testing and geochemical sampling may be incorporated into these detailed studies. The exact number of areas investigated will largely depend on the inherent complexity of the conceptual model and also on economics.

The overall objective of these site characterization studies must be to demonstrate the geomechanical and hydrogeologic suitability of the candidate site as well as the long-term stability of the groundwater flow system. It is anticipated that the Nuclear Waste Management Organization will have to provide a detailed site investigation and interpretation methodology, coupled with a traceable process for continuous refinement of the subsurface conceptual model, to ensure confidence in the resulting repository safety case.

OPG is investigating several methods to facilitate the integration and interpretation of large, site investigation data sets. A 3-dimensional visualization tool, VULCAN, used extensively throughout the international resource exploration community, has been integrated into the moderately fractured rock experiment at AECL's Underground Research Laboratory for the purpose of facilitating and gaining confidence in the developing conceptual model of the subsurface. OPG is also exploring the applicability of using an immersive data visualization and interpretation centre to further enhance the integration of large, 3-dimensional, cross-disciplinary, data sets. Such a facility could also help to communicate the transparency of the conceptual model development process to third parties. To further enhance the value-added of lineament analyses, the development of geostatistical methods for the generation of subsurface discontinuity models is also being pursued.

5.03 Siting - Methods

5.03.01 Siting - Methods - General

PARTICIPANT COMMENTS

Canadian Geoscience Council

At the scale of the candidate areas (~400 km2), the availability of good ground geological data and good ground geophysical data, as well as modern geological cross-section reconstruction and analysis technques is crucial in giving insights into the 3-D nature of the area before drilling and shaft siting are decided upon. [Comment 1041, Source Document tec002, Page 16, Section 3.2.2]

Natural Resources Canada

The EIS does not demonstrate a capability for characterizing surficial geological materials at specific sites. [Comment 711, Source Document gov005, Page 19, Section 7.11]

this document does not cite IAEA documents that deal with siting of geological disposal facilities.... A comparison of AECL's proposed procedures with IAEA guidelines should be conducted to ensure consistency with international standards. [Comment 742, Source Document ph2gov001, Page sit3]

Northwatch (Richardson)

The account of characterisation techniques in the EIS is also deficient in that it concentrates on surface-based techniques, whereas much of the final characterisation will be conducted underground..... While excellent work may be performed at the Whiteshell URL, this vital linkage between experimentation and site characterisation, and the time dependency involved, is not made clear in the EIS. [Comment 1516, Source Document ph2pub009, Page 08, Section 2]

while the R-Siting document gives an excellent overview of the "state of the art" in terms of site characterisation techniques, there is very little in terms of a discussion of the applicability of some of them to the problem in hand, and little discussion of the need for development of underground methods. [Comment 1517, Source Document ph2pub009, Page 08, Section 2]

Science for Peace (Energy Working Group)

prior to site selection AECL should demonstrate the viability of their new tools, techniques, and materials. [Comment 1712, Source Document ph2pub034, Page 4]

OPG RESPONSE

Modern data interpretation and subsurface reconstruction techniques should be incorporated into the earliest possible stages of a siting process. Surface geologic and geophysical data can be input to 3dimensional visualization tools to aid development of an initial conceptual model of the subsurface environment. If the features of the preliminary conceptual model prove favourable for a deep geologic repository, based on established siting criteria, then subsequent stages of data gathering and model refinement could proceed with stakeholder approval. An iterative process between field characterisation, conceptual model development and performance assessment would further advance the understanding of, and confidence in, geosphere properties, as well as long-term barrier performance.

OPG is supporting activities to improve the interpretation and utilization of geologic data for siting purposes. A consistent methodology is being developed for the interpretation and presentation of surface lineament data within a GIS framework. Lineament interpretation makes use of satellite and air photo imagery, geophysical data, and surface mapping studies to help infer the nature of structural discontinuities (faults) that could influence repository construction and long-term performance. Geostatistical methods are being applied to create sets of equally-probable 3-dimensional models of subsurface fracture geometry based on lineament analysis. Visualization tools are being used to help synthesize large geologic and hydrogeologic data sets into a coherent conceptual model of the

subsurface environment (Gierszewski et al. 2001). A key goal of these initiatives is to better ensure traceability in the interpretation of geometrically complex multi-disciplinary data sets and allow the development of flow system hypothesizes that may guide, and be tested by, subsequence site characterisation activities.

References

Gierszewski, P., S.B. Russell, F. Garisto, M.R. Jensen, T.F. Kempe, P. Maak and G.R. Simmons. 2001. Deep geologic repository technology program - annual report 2000. Ontario Power GenerationReport 06819-REP-01200-10055-R00.

5.03.02 Siting - Methods - Evaluation

PARTICIPANT COMMENTS

Atomic Energy Control Board

AECL does not demonstrate that it is feasible to collect the quantities and qualities of data and information required to demonstrate that a site is acceptable.... AECL has not addressed adequately the differences in scale between the URL investigations and those required for a nuclear fuel waste repository.... The EIS does not identify the limits of what can be known about a site with current and reasonably achievable technology, such as the type, quantity and spatial coverage of information that will be attainable.... The limitations in characterizing these and other parameters on the scale of the repository need to be compared to analytical requirements to determine whether it is possible to demonstrate that the reference design can comply with safety criteria. [Comment 565, Source Document gov002, Page 19, Section A.5.1]

[The EIS] does not critically evaluate the techniques and technologies or discuss their limitations. [Comment 912, Source Document gov002, Page 76, Section E.1]

The report does not fully describe and critically review the regional hydrogeological methods that should be carried out during reconnaissance phase (Siting PRD, p. 82). [Comment 909, Source Document gov002, Page 77, Section E.1.1]

[The EIS] does not critically evaluate the techniques and the existing technology for collecting, integrating and interpreting that information. [Comment 913, Source Document gov002, Page 77, Section E.1.1]

there are insufficient discussions of the current capabilities of cross-hole seismic tomography and cross-hole radar tomography (Siting PRD, p. 163), as well as the need for additional development of these techniques. There is not a critical assessment of the capabilities and limitations of multiple borehole hydrogeological tests as part of the site characterization program (Siting PRD, p. 175). Nor is there critical review of the use of multiple borehole groundwater tracer tests for the determination of the rock porosity, permeability and dispersion (Siting PRD, p. 176). [Comment 685, Source Document gov002, Page 78, Section E.1.2]

A critical review and inter-comparison of different geological and geophysical methods and techniques is lacking (Siting PRD, p. 69). No critical review of borehole geophysical methods and technology is presented, and no comparisons and correlations of the results of geophysical surveys with core logs, TV logs or data obtained by other methods are presented (Siting PRD, p. 143). [Comment 911, Source Document gov002, Page 78, Section E.2.1]

Joint Committee of the Canadian Academy of Engineering and the Royal Society of Canada

with respect to the major issue of assessing the effects of fractures on groundwater flow, it is not clear what the preferred hierarchy of methods would be. Which methods are considered to be the most widely applicable and reliable? I could not find this type of summary evaluation of methodology in the reports. [Comment 1151, Source Document tec003, Page w09, Section 8]

Scientific Review Group

Characterization methods for site screening (R-Siting 1994: Section 4, pp.59-90) are reasonable; however the relative importance of these methods has not been discussed, and it is not clear whether all of the various methods or lines of evidence are actually needed or how they can be combined to screen sites... [Comment 16, Source Document tec004, Page 108, Section A-2.1.6]

OPG RESPONSE

Siting methods are continuously evolving as a function of improving sensor technology, hardware

computing/storage/visualization capabilities, data processing, numerical analysis and geostatistical techniques. The hierarchy of site characterization methods applicable to deep repository siting is therefore in a constant state of change and can only be formalized when actual siting activities begin. One example would be some particular non-destructive method that has previously shown limited applicability, but through improvements in sensor technology and interpretative techniques could, in the future, result in a very effective and economical site characterization method. With regards to the siting of a deep geologic repository in the Canadian Shield, siting methods that improve the identification and characterization of groundwater pathways (fractures and fracture zones) are of great significance. Research in fracture flow and contaminant transport is on-going throughout the international community focused in the areas of nuclear waste disposal, hydrocarbon resource evaluation and exploitation, karst genesis, mine design and water resource management.

OPG maintains close association with international organizations presently involved in repository siting technology development such as SKB in Sweden and Posiva in Finland. OPG is undertaking research to improve the understanding, characterization and numerical modeling of groundwater flow and radionuclide transport at various scales in fractured media: in a 1 m2 fracture for the Quarried Block Experiment (QBE), in a 125,000 cubic metre block of moderately fractured rock (MFR Experiment) and at the regional groundwater flow system scale (Gierszewski et al. 2003). It is anticipated that an improved understanding of flow and transport behaviour at various scales will ultimately reinforce future repository safety assessment strategies.

As part of the MFR Experiment, 3-dimensional visualization tools are being utilized to store, integrate and interpret large data sets for the purpose of improving the conceptual model of the subsurface. Developments in 3-dimensional visualization and earth modeling techniques, including immersive data interpretation, have proven invaluable in providing a cross-disciplinary platform for synthesizing large, site characterization data sets. These activities aid in the demonstration and articulation of site characteristics and geologic reasoning underlying predictions of geosphere performance.

References

Gierszewski, P., S.B. Russell, A. D'Andrea, F. Garisto, M.R. Jensen, T.F. Kempe, P. Maak, G.R. Simmons and A. Vorauer. 2003. Deep geologic repository technology program - annual report 2002. Ontario Power Generation Report 06819-REP-01200-10100-R00.

5.03.03 Siting - Methods - Geophysics

PARTICIPANT COMMENTS

Atomic Energy Control Board

non-intrusive geophysical techniques will be required to verify the existence of a waste exclusion zone.... it appears that current non-destructive (i.e., geophysical) methods cannot provide appropriate data of sufficient confidence to adequately characterize a waste exclusion zone. [Comment 686, Source Document gov002, Page 78, Section E.1.2]

Natural Resources Canada

Satellite imagery could be used to identify agricultural activity, forestry or wildlife habitats. [Comment 745, Source Document ph2gov001, Page sit4]

Recent advances in the processing of airborne EM data allow the computation of conductivity sections that provide a 3-D image of the subsurface. These were not available when the examples of reconnaissance site evaluations were done. [Comment 746, Source Document ph2gov001, Page sit5]

In Table 6-1, item 3 on ground-based geophysical surveys, ground VLF-EM, VLF-EM resistivity, magnetotelluric (MT) and audio-magnetotelluric (AMT) methods should have been included, the former for shallow depths and the latter for deep investigations. Sonar surveys of lake bottom sediments are indicated as tools to be used to identify areas of gas release. It is not clear how these surveys will distinguish between features indicating biogenic gas release and those related to groundwater release. [Comment 750, Source Document ph2gov001, Page sit5]

Northwatch (Richardson)

Nowhere in either the EIS or R-Siting do AECL point out that it is still not certain that existing geophysical techniques are yet fully capable of satisfactorily delineating GDFZ's across a candidate site. [Comment 1519, Source Document ph2pub009, Page 12, Section 3]

Scientific Review Group

the discussion of the role of satellite and airborne imagery (R-Siting 1994: p.61ff) is overly optimistic. The correlation between lineaments that are discernible in this kind of imagery and major fractures in the rock mass is not straight-forward. Nevertheless, the imagery is very important when used in conjunction with ground observations for delineating boundaries between different rock types, and boundaries formed by faults. The magnetic anomaly lineaments (R-Siting 1994: Figure 4-2, p.67) may be very helpful in tracing structural features that are identified in outcrops or boreholes, but they do not make it possible to identify those structures without detailed observations that come from outcrop and borehole investigations. The relative importance ascribed to geophysical remote sensing in reconnaissance investigations during the site screening process is not justified by the information that is presented in Section 4.4 (R-Siting 1994: pp.69-80).... Airborne radiometric surveys may provide useful information about the abundance and distribution of rocks as characterized by contents of thorium, uranium and potassium, at a large scale, but this type of survey reveals little about the Lac du Bonnet batholith, over and above surface investigations, that would be pertinent for site screening. It is unfortunate that the application of electrical methods (R-Siting 1994; p.75) for locating fractures and contrasts (R-Siting 1994: p.79) in various rock types was not better documented, even for the WRA case study.... [Comment 511, Source Document tec004, Page 109, Section A-2.1.6]

OPG RESPONSE

The application of airborne, ground-based and borehole geophysical techniques plays a significant role in providing characterisation data during the various stages of the siting process. As with all methods based on the acquisition and processing of electrical signals, continuous improvement in sensor technology, mass data storage devices, computational

hardware and interpretative techniques help to extend the applicability and usefulness of several geophysical techniques. Indeed, technology development can result in certain site investigation methods becoming redundant.

The benefit of applying various geophysical methods in the repository siting process is that large sitespecific data sets can be generated in a relatively short period of time. The challenge is in the proper interpretation and integration of these data sets for the purpose of developing a proper understanding of the lithologic, structural and geochemical characteristics within a siting region, and the subsequent projection of these characteristics into the subsurface at a candidate site(s). It is important to note that geophysical methods are most useful in mapping the location of contrasting material properties as well as the extent of relatively homogeneous surface and subsurface material properties.

Geophysical methods, for example airborne magnetic and gravity surveys, can be used as stand-alone techniques for delineating large geologic structures within siting regions. Satellite and airborne imagery can also be used to identify the approximate location and orientation of large surface lineaments at the early stages of the siting process. However, more detailed ground-based geophysical methods, coupled with detailed surface and subsurface geologic mapping and testing, are required to help establish the boundaries and internal geometry necessary to develop a conceptual site model.

The Nuclear Waste Management Organization, responsible for undertaking the siting process, will have to develop a proper strategy for the application of airborne, ground-based and borehole geophysical methods. Such a strategy will depend on the state-of-technology at that time, on the data quality objectives for the various stages of the siting process and most importantly on the data integration and interpretation methods applied to conceptual site model development and subsequent repository performance assessment.

5.03.04 Siting - Methods - Geochemistry

PARTICIPANT COMMENTS

Atomic Energy Control Board

AECL has estimated the redox potential of URL and WRA groundwaters largely on the basis of electrode potential measurements (Gascoyne, 1989). Because these waters are, in general, poorly poised (ie. low concentrations of electroactive redox couples such as Fe2+/Fe3+) it is inappropriate to interpret the measured potentials as thermodynamically meaningful redox potentials. [Comment 630, Source Document gov002, Page 56, Section C.3.1(i)]

Scientific Review Group

Results from geochemical studies conducted by the AECL on distribution and timeframe for mobility of uranium, thorium and rare earth elements, in rocks and fractures at URL and other Research Areas ... are available; however, how these results would be considered in site evaluation is not discussed. [Comment 464, Source Document tec004, Page 089, Section 7.2]

There is a cursory treatment of geochemical methods for groundwater analysis, and its implications (R-Siting 1994: Section 4.4.4, p.85).... the profound implications of fluid source and fluid residence time are not adequately discussed. Chlorine and stable isotopes are not mentioned in Section 4.4.4, but are listed only as candidates for analysis elsewhere. [Comment 13, Source Document tec004, Page 108, Section A-2.1.4]

The capability to determine the sorption capacity of fracture surfaces during the site evaluation phase is not adequately documented.... A major limiting factor is the amount of fracture surface area available for such sorption, and the limited duration of a feasible experiment. It is not stated how the surface area, and its effect on sorption, will be determined. [Comment 23, Source Document tec004, Page 113, Section A-2.2.3]

OPG RESPONSE

Hydrogeochemistry assumes an important role in the understanding of the interconnectivity of groundwater flow paths and long-term stability of the flow system at local and regional scales. In the case of a fractured plutonic rock setting, Gascoyne (2000) describes hydrogeochemical studies conducted at the Whiteshell Research Area (WRA) between 1980 and 1994. This case study explains groundwater sample collection methodologies, Quality Assurance measures, elemental and environmental isotopic analyses and the interpretation of the WRA data set in the context of groundwater origin and residence times. The report provides an unique examination of geochemical methods and lessons learnt as applied to flow system characterisation. Such techniques could be applied during a future site characterisation program should there be a requirement.

Within OPG's geoscience program, further efforts have been taken to demonstrate the utility of geochemical methods for site characterisation. This includes the WRA Paleohydrogeologic Study, the purpose of which is to examine WRA fracture infill minerals for petrologic, mineralogic and isotopic evidence of past recharge by low salinity, oxygenated glacial recharge (McMurry 2000). This is part of a geoscience technical program goal to better understand long-term flow system dynamics (i.e. scale 1000's a) and to assess potential mechanisms responsible for maintaining poised redox conditions at the repository horizon. Further work involves examining the influence of peri-glacial (I.e. permafrost) conditions on groundwater compositions and fracture mineralogy in crystalline flow domains. As part of this program objective, preliminary planning of a joint-international study at the Lupin gold mine in Nunavut has been initiated. Through a partnership with SKB, Posiva, Nirex and the Finnish Geological Survey, the evolution of elemental and isotopic groundwater compositions at the mine site will be assessed. This project is intent on examining the hydrogeochemical characteristics of flow system affected by glacial cycles and permafrost, as might be expected in a Canadian Shield setting.

References

Gascoyne, M. 2000. Hydrogeochemistry of the Whiteshell Research Area. Prepared by Gascoyne GeoProjects Inc.. Ontario Power Generation, Nuclear Waste Management Division Report 06819-REP-01200-10033-R00.

McMurry, J. 2000. Evaluating effects of deep recharge by low-salinity, oxidizing groundwater: a geochemical modeling case study. Prepared by Atomic Energy of Canada. Ontario Power Generation, Nuclear Waste Management Division Report 06819-REP-01300-10007-R00.

5.03.05 Siting - Methods - Stress

PARTICIPANT COMMENTS

Atomic Energy Control Board

Methods to quantify and assess the regional geological stresses are not adequately addressed. [Comment 681, Source Document gov002, Page 77, Section E.1.1]

the need and potential for technology developments to measure in situ stresses in boreholes drilled from surface at depths below approximately 350 m is not adequately discussed (Siting PRD, p. 43 and p. 159). [Comment 684, Source Document gov002, Page 77, Section E.1.2]

Scientific Review Group

The relationship between rock stress and site evaluation has not been explicitly considered. The unexpectedly high differential stresses encountered at depth in some Canadian Shield rocks (Martin 1990) that could be unfavourable to disposal vault construction and performance are not considered within the site screening and evaluation technologies presented in R-Siting... The document does not deal adequately with the difficulty in measuring in situ stress, and in relating these point measurements to geotechnical and hydrogeologic properties.... the inability to determine stresses below 300 m is a serious limitation in evaluating the siting of a disposal vault. [Comment 25, Source Document tec004, Page 114, Section A-2.2.4]

OPG RESPONSE

OPG is completing an evaluation of the Deep Doorstopper Gauge System (DDGS) as a viable alternative to the hydraulic fracturing method for the determination of in situ stress at depth. This project will also include a state-of-technology report on in situ stress determinations in shallow and deep boreholes.

OPG recognizes the significance of high in situ stresses at depth in Canadian Shield environments and is pursuing the less sensitive in-room emplacement option in parallel with the in-floor borehole emplacement option. It is also recognized that the magnitude and orientation of the in situ stress field has an impact on geotechnical and hydrogeologic properties such as fracture aperture and therefore permeability.

5.03.06 Siting - Methods - Hydrogeology

PARTICIPANT COMMENTS

Environment Canada

the limits of low-permeability hydraulic testing methods are not adequately discussed nor are the potential implications of these limits satisfactorily addressed. Given the limitations of geophysical methods, convincing evidence is not presented that AECL will be able to sufficiently characterize the hydrogeological properties and any fracture patterns in the low permeability rock mass that will separate the waste emplacement room from the more permeable fracture zones. [Comment 836, Source Document gov003, Page 09, Section 2.2]

Natural Resources Canada

there is no mention of temperature gradient logs which have been found to be very useful for delineating fracture zones with water inflow. [Comment 752, Source Document ph2gov001, Page sit6]

Multiple groundwater tracer tests are cited as methods for characterizing fracture zone porosity, permeability and dispersion characteristics. The nature of the tracer to be used in these tests is not specified. Organic tracers will yield less reliable results than radioactive tracers. [Comment 753, Source Document ph2gov001, Page sit6]

Northwatch (Richardson)

there is no discussion of the potential problems associated with testing hydraulic parameters in boreholes drilled in heterogeneous crystalline rocks. [Comment 1513, Source Document ph2pub009, Page 06, Section 2]

the validity and application of the results of tracer tests should be discussed in considerable detail by AECL.... It is vital that AECL have confidence in such vital parameters as flow rate and sorption coefficients etc., many of which rely on tracer tests for their derivation. [Comment 1522, Source Document ph2pub009, Page 15, Section 3]

delineation of the major water-conducting pathways in and around the environs of a repository is still not achievable in sufficient detail. [Comment 1556, Source Document ph3pub088, Page 09, Section 4]

Work in Sweden at the underground laboratory at Aspo has suggested that much of the data used in earlier tracer experiments is effectively useless, given that the assumptions underlying their interpretations appear to be indefensible. [Comment 1558, Source Document ph3pub088, Page 10]

Northwatch and Saskatchewan Environmental Society (Richardson)

Although of crucial concern to efforts to understand hydrogeological conditions at a given site, the ability to confidently locate all the fractures likely to be of importance is still not available. Given that it also difficult to predict which fractures will actually transmit water in the future, this remains an intractable problem. [Comment 1598, Source Document ph2tec037, Page 14, Section 4.2]

Scientific Review Group

The flow dynamics of groundwater are controlled, by the distribution of fractures and their permeabilities, by the distribution of saline groundwater, by the driving forces due to gravity and pressure differentials and by temperature distribution, among other factors. AECL has shown an awareness of all these controlling factors; however a convincing capability to characterize them for the purposes of site screening and evaluation is shown only in relation to permeability (to fractured rock) and groundwater salinity. [Comment 465, Source Document tec004, Page 090, Section 7.2]

OPG RESPONSE

The hydrogeologic characterization of fractured-porous groundwater flow systems at scales necessary for used fuel repository performance assessment is a complex undertaking. The OPG program continues to focus on the development of site characterization skills required for conceptual flow system model development and the prediction of geosphere barrier performance. Key research areas examine technical issues surrounding long-term groundwater flow system evolution and the capabilities and limitations of numerical methods for predicting flow and transport relevant to repository safety.

The technical program is aware of uncertainties inherent in site characterization and is focused on development of field testing techniques to provide bounds or constraints on such uncertainties. This includes the monitoring of international research and development work at facilities such as the SKB Aspo Hard Rock Laboratory in Oskarshamn, Sweden. Further, the technical program is examining the integration of multi-disciplinary data sets to yield reasoned and traceable site specific conceptual flow system models that support performance assessment.

A key element of the safety case involves the rationalization of a conceptual flow system model. It is through this process that multi-disciplinary field characterization data is combined into an internally consistent framework. Development of the conceptual model requires planning and a prior knowledge of field testing techniques, governing flow/transport system processes, and techniques for data integration. With regard to characterisation and numerical flow system simulation, key geoscience work program activities are described in Gierszewski et al. (2001). Among the work programs related to hydrogeologic characterization are:

- 1) Moderately Fracture Rock Experiment (Vandergraaf et al. 2001)
- 2) In-situ Diffusion Experiment (Vilks et al. 2000)
- 3) Regional Flow System Analysis (Sykes et al. 2002)
- 4) Review of Anomalous Hydraulic Heads (Chan et al. 1998)
- 5) Whiteshell Research Area Hydrogeochemistry (Gascoyne 2000)
- 6) Paleohydrogeology Recharge Glacial Meltwater (McMurry 2000)

These work programs focus on hydrogeologic issues that aid in the characterisation and understanding of spatial and temporal flow system properties and boundary conditions. The Moderately Fractured Rock (MFR) and In-situ Diffusion experiments are refining methods to characterise and simulate advective and diffusive mass transport in fractured crystalline rock. This includes application of innovative hydraulic well testing techniques (Roberts 2002), geostatistical methods (Chan et al, 2001) and the creation of the MFR Modeling Task Force. As part of the MFR experiment, visualisation software and virtual reality technologies are being applied to aid flow system data integration and to improve clarity in development of the conceptual flow system model (Cotesta and Kaiser 2002).

Work continues in the Regional Flow System Analyses to illustrate and define through numerical simulation hydrogeologic

issues of importance to repository siting. This includes investigating the role of gravity and density gradients and spatially variable permeability fields on groundwater flow paths and residence times. The Whiteshell Research Area Hydrogeochemical, Anomalous Hydraulic Head and Paleohydrogeologic studies focus on improving the understanding of flow system dynamics. Such studies yield evidence of evolving flow system properties (i.e., large domains of low permeability rock; penetration of oxygenated glacial recharge; long-term hydraulic boundary conditions; role of peri-glacial conditions) that aid confidence in flow system conceptualization.

References

Chan, T., P.A. O'Connor and F.W. Stanchell. 1998. Finite-element modeling of effects of past and future glaciation on the host rock of a used nuclear fuel waste vault. Prepared by Atomic Energy of Canada Limited. Ontario Hydro Nuclear Waste Management Division Report 06819-REP-01200-0020 R00.
Chan, T., F.W. Stanchell, R.M. Srivastava and N.W. Scheier. 2001. Stochastic conditional flow and transport simulations of tracer test No. 2 (TT2) of the Moderately Fractured Rock Experiment at the Underground Research Laboratory: a geostatistics case study. Prepared by Atomic Energy of Canada Limited and FSS Canada Consultants Inc. Ontario Power

Generation, Nuclear Waste Management Division Report 06819-REP-01200-10039-R00.

Cotesta, L. and P.K. Kaiser. 2002. Application of virtual reality technology in site characterization: Moderately Fractured Rock Experiment pilot project. Prepared by MIRARCO. Ontario Power Generation Nuclear Waste Management Division Report 06819-REP-01300-10058-R00.

Gascoyne, M. 2000. Hydrogeochemistry of the Whiteshell Research Area. Prepared by Gascoyne GeoProjects Inc.. Ontario Power Generation, Nuclear Waste Management Division Report 06819-REP-01200-10033-R00.

Gierszewski, P., S.B. Russell, F. Garisto, M.R. Jensen, T.F. Kempe, P. Maak and G.R. Simmons. 2001. Deep geologic repository technology program - annual report 2000. Ontario Power Generation, Nuclear Waste Management Division Report 06819-REP-01200-10055-R00.

McMurry, J. 2000. Evaluating effects of deep recharge by low-salinity, oxidizing groundwater: a geochemical modeling case study. Prepared by Atomic Energy of Canada Limited. Ontario Power Generation, Nuclear Waste Management Division Report 06819-REP-01300-10007-R00.

Roberts, R.M. 2002. Moderately Fractured Rock Experiment: well test analysis using nSIGHTS. Prepared by Sandia National Laboratories. Ontario Power Generation, Nuclear Waste Management Division Report No. 06819-REP-01300-10062-R00.

Sykes, J., E. Sudicky, M. Jensen, S. Normani and R. McLaren. 2003. Modeling strategy to assess regional-scale groundwater flow within a Canadian Shield setting. Geological Society of America Annual Meeting, Denver, US.

Vandergraaf, T.T., T. Chan, E.T. Kozak, R.A. Everitt, J.D. Ross, F.W. Stanchell and P. Vilks. 2001. Moderately Fractured Rock Stage 2, Phase 3 Experiment Plan and Schedule for FY 2001/2002. Prepared by Atomic Energy of Canada Limited. Ontario Power Generation, Nuclear Waste Management Division Report 06819-REP-01300-10032-R00.

Vilks, P., J.J. Cramer, T.W. Melnyk, F.W. Stanchell, N.H. Miller and H.G. Miller. 1999. In-situ diffusion in granite: phase I final report. Prepared by Atomic Energy of Canada Limited and Geological Survey of Norway (NGU). Ontario Power Generation, Nuclear Waste Management Division Report 06819-REP-01200-0087-R00.

5.03.07 Siting - Methods - Existing Information

PARTICIPANT COMMENTS

Canadian Coalition for Nuclear Responsibility (Regroupement pour la surveillance du nucléaire)

Le granite, type de roche préconisé pour le stockage des d'echets nucléaires, est une des roches qu'on connaît le moins bien. On l'a peu étudié car on y trouve peu de gisements de minéraux. La circulation de l'eau, en particulier, en milieu granitique, est teès peu documentée. [Granite, the recommended rock for disposal, is one of the least understood rocks. It has been little studied because mineral deposits are seldom found. In particular, groundwater flow in granite is very poorly documented.] [Comment 1904, Source Document ph3pub192, Page 1]

Natural Resources Canada

the Geological Survey of Canada's National Geochemical Reconnaissance (NGR) ... database contains an extensive survey of Uranium and other metals in lake sediments and in lake water, for the Ontario portion of the Canadian Shield. Furthermore, this database also contains supporting surveys of lake depths and areas for the same regions, that may be more useful than the dataset of the Ontario Ministry of Natural Resources cited on page 97. [Comment 717, Source Document ph2gov001, Page bio2]

The document discusses the soil gas (radon and helium) measurement technique used to detect locations where deep groundwater might be discharging from the subsurface bedrock fractures. It is noted that the GSC has compiled a National Geochemical Reconnaissance data base that would be useful in obtaining similar information. This data base has excellent coverage of shield areas in Ontario, with measurements of 16 elements present in lake and stream sediments and associated waters. [Comment 747, Source Document ph2gov001, Page sit5]

Northwatch

the EIS should provide criteria for utilizing (and method for validating) pre-existing information [Comment 1386, Source Document pub046, Page 16, Section d]

Scientific Review Group

the document provides no distillation of the wealth of available quantitative data on the frequency, depth extent, age, ages of reactivation of fractures, or on fracture aperture, interconnectivity, secondary mineralogy or radionuclide characteristics of fractures; or on the range of variability of these properties that could be used to develop and rank criteria in site selection.... The document describes important technical factors to be considered in site evaluations (R-Siting 1994: p.91).... However, there is inadequate documentation of the range of characteristics of these factors, and inadequate quantitative information on ranges of variation that exists from the various AECL research areas in the Canadian Shield. [Comment 6, Source Document tec004, Page 106, Section A-2.1.4]

OPG RESPONSE

The comments in this category speak to two separate technical siting issues: i) the use of existing public domain data and ii) the presentation of existing geoscientific data gathered at research areas during the Canadian Nuclear Fuel Waste Management Program. With regard to the first, a key interest of the technical program is to maintain an awareness of public domain data sets relevant to siting. With the development of Geographic Information Systems (GIS) and other digital data presentation/visualisation software, a particular concern is the availability of current digital remote sensing, geologic, geophysical, hydrologic, water well and environmental data sets. A specific example of GIS application and data set integration is described by Sikorsky et. al. (2002). This study generated a revised lineament interpretation for the Whiteshell Research Area (approx. 2000 km2) that involved evaluation of Landsat, RadarSat, aerial photography (2m resolution), geologic data,

airborne geophysical data, and overburden thickness data. A key objective of the study was to demonstrate a traceable methodology for the interpretation and archiving of geoscientific data relevant to site characterisation. This approach could also include spatially relevant political and social siting data.

The geoscience information gathered at research areas throughout the Canadian Nuclear Fuel Waste Management program is available in separate AECL Technical Reports (TR-series reports). These data have not been interpreted or integrated with respect to the development of a rigorous conceptual model for individual sites (i.e. Whiteshell, East Bull Lake; Atikokan).

Through the development of such models, a better understanding of flow system variability including bedrock lithology, geologic structure, fracture orientation/frequency, fracture infill mineralogy, permeability distributions, fracture generation mechanisms, hydrogeochemistry, hydraulic head distributions and the like would be developed. Given the unique nature of geoscientific studies at these research areas, development of comparable conceptual models as part of a Case Study may be warranted. This would better enable performance assessment to articulate the range of conditions observed in Shield settings.

Reference

Sikorsky, R.I., M. Serzu, D. Tomsons and J. Hawkins. 2002. A GIS-based lineament interpretation method and case study at the Whiteshell Research Area. Prepared by Atomic Energy of Canada Limited. Ontario Power Generation Nuclear Waste Management Division Report 06819-REP-01200-10073-R00.

5.03.08 Siting - Methods - Geographical Information System

PARTICIPANT COMMENTS

OECD/NEA Review Group

We support the use of visualisation techniques using GIS and 3-D graphical geological simulation models to illustrate and explain features of areas and communities which will be important in decision-making. [Comment 1243, Source Document tec001, Page 16, Section 5.1]

Scientific Review Group

The application of computer-based geographical information systems (GIS) has been omitted from site screening and evaluation methods used at the WRA... A demonstration of this approach would have been helpful. [Comment 17, Source Document tec004, Page 109, Section A-2.1.7]

OPG RESPONSE

The application of Geographic Information Systems and multi-dimensional visualisation software is considered an important element in the OPG program. A key goal in application is to improve the traceability and repeatability of analyses that require integration of geometrically complex multidisciplinary data sets. Pilot projects that attempt to demonstrate the utility of such technologies have been undertaken including the GIS-based Whiteshell Research Area Lineament Analysis (Sikorsky et al. 2002) and the Regional Flow System Analyses (Sykes et al. 2002). With respect to visualisation, the Underground Research Laboratory (URL) Moderately Fractured Rock (MFR) experiment used the code VULCAN to aid in data integration and conceptual model development. In addition, a pilot project was recently completed, using both MFR and URL data sets to assess immersive visualisation technology at the Virtual Reality Laboratory at Laurentian University (Cotesta and Kaiser 2002). The OPG program will continue to foster the development and application of GIS, visualisation and electronic data management systems that better enable the communication of sub-surface conditions relevant to demonstrating long-term repository and geosphere performance.

References:

Cotesta, L. and P.K. Kaiser. 2002. Application of virtual reality technology in site characterization: Moderately Fractured Rock Experiment Pilot Project. Prepared by MIRARCO. Ontario Power Generation Nuclear Waste Management Division Report 06819-REP-01300-10058-R00. Toronto, Ontario.

Sikorsky, R.I., M. Serzu, D. Tomsons and J. Hawkins. 2002. A GIS-based lineament interpretation method and case study at the Whiteshell Research Area. Prepared by Atomic Energy of Canada Limited. Ontario Power Generation Nuclear Waste Management Division Report 06819-REP-01200-10073-R00.

Sykes, J., E. Sudicky, M. Jensen, S. Normani and R. McLaren. 2003. Modeling strategy to assess regional-scale groundwater flow within a Canadian Shield setting. Geological Society of America Annual Meeting, Denver, US.

5.04 Siting - Case Studies

PARTICIPANT COMMENTS

Scientific Review Group

Whereas the overall principles of the siting process are well stated (R-Preclosure 1994: pp. vi, 4-1 and 4-2), examples of methods and approaches used in the siting of other facilities, most notably nuclear-related facilities, would have strengthened the argument [Comment 116, Source Document tec004, Page 148, Section D-2.1.17]

OPG RESPONSE

Development and implementation of a repository siting methodology will be the responsibility of the Nuclear Waste Management Organization, should the federal government adopt deep disposal as the preferred long-term used fuel waste management strategy. This approach is consistent with the Nuclear Fuel Waste Act.

With regard to siting case studies, the Canadian program continues to maintain ties and monitor developments in international radioactive waste repository programs. This includes the Swedish siting program which after ten years of experience has identified four alternative candidate sites within the municipalities of Oskarshamn, Nykoping and Tierp/Osthammar for sub-surface characterisation (SKB 2001). Within the Finnish program, government approval has been received for the development of a used fuel repository at the coastal Olkiluoto site, one of four candidate sites previously investigated (Posiva 2000). These programmes, among others, demonstrate successful social and technical approaches to repository siting.

References

Posiva. 2000. Disposal of spent fuel in Olkiluoto bedrock: programme for research, development and technical design for the pre-construction phase, POSIVA Report 2000-14. Helsinki, Finland.

SKB. 2000. Integrated account of method site selection and programme prior to the site investigation phase. SKB Technical Report TR-01-03. Stockholm, Sweden.

5.05 Siting - Research

PARTICIPANT COMMENTS

Atomic Energy Control Board

there is no discussion of the technological developments that are needed to collect the information and perform integrated site characterization at the spatial scales required. [Comment 914, Source Document gov002, Page 78, Section E.2]

Environment Canada

It is important that AECL continue to develop and refine methods for the characterization of lowpermeability rock. [Comment 915, Source Document gov003, Page 09, Section 2.2]

Joint Committee of the Canadian Academy of Engineering and the Royal Society of Canada

We also note the emergence of new insights into rock properties, the ways in which fluids move through and react with rocks of low permeability and the role of bacteria in deep environments, as ample illustration of the need for continued research to guide the selection and characterisation of a site. [Comment 1187, Source Document ph3tec001, Page 5]

OECD/NEA Review Group

The declared AECL goal of using analyses of the hydrogeology to 'fine-tune' the positioning of the vault is shared by many other programmes. The measurement and analysis tools necessary for such a step require further refinement. [Comment 1210, Source Document tec001, Page 09, Section 3.2.1]

The Group would be strongly supportive of a more extensive programme of work on the hydraulic, hydrochemical and geotechnical properties of the sparsely fractured rock. Solute transport processes are determined by the micro-scale features of the rock body. [Comment 1213, Source Document tec001, Page 10, Section 3.2.1]

international experience and Canadian opinion indicates that 'less-good' (i.e. more fractured) rock could also provide adequate margins of safety, although analyses of the behaviour of fractured rock would be very different to those used in the Reference Case. Further progress in siting and safety assessment would benefit from the continued development of modelling and characterisation methods for such rock. [Comment 1214, Source Document tec001, Page 10, Section 3.2.1]

AECL proposes to fix the ultimate depth and location of the vault at a chosen site on the basis of a quantitative understanding of the hydrogeology at a suitably fine scale. This is also an objective in some other national programme. The resolution and the reliability of hydrogeological modelling must improve if this is to be feasible. [Comment 1249, Source Document tec001, Page 17, Section 5.1]

OPG RESPONSE

The Canadian program continues to conduct geoscience research and development to preserve and advance skills unique to the understanding of fractured-porous shield settings. Gierszewski et al. (2003) provides a description of geoscience research activities. These activities are divided into two primary areas i) site characterisation and ii) performance assessment. In part, research activities have been undertaken to address outstanding geoscience issues from the Environmental Impact Statement and Second Case Study technical reviews (Jensen and Goodwin, 1999). A key focus involves conceptual model development and the application of performance assessment tools to illustrate long-term flow system stability. Conceptual model development involves the integration of multi-disciplinary data to describe flow system properties, geometry and boundary conditions relevant to repository performance. The primary goal of the latter is to assess complementary performance assessment modeling techniques that enable flow system evolution and uncertainty to be explored for a range of anticipated Shield conditions.

References

Gierszewski, P.J., S.B. Russell, A. D'Andrea, F. Garisto, M.R. Jensen, T.F. Kempe, P. Maak, G.R. Simmons and A. Vorauer. 2003. Deep Geologic Repository Technology Program - Annual Report 2002. Ontario Power Generation, Nuclear Waste Management Division Report 06819-REP-01200-10100-R00.

Jensen, M.R. and B. Goodwin. 1999. Confidence in geosphere performance assessment - The Canadian nuclear fuel waste disposal program: A retrospective. Proceedings 4th GEOTRAP Workshop, Confidence in Models of Radionuclide Transport for Site Specific Performance Assessment, Carlsbad, New Mexico, USA.

5.06 Siting - Quality Assurance

PARTICIPANT COMMENTS

OECD/NEA Review Group

It is important to have in place an appropriate quality assurance programme at the start of site selection and characterisations to allow sensible and traceable decisions to be made. [Comment 1246, Source Document tec001, Page 16, Section 5.1]

OPG RESPONSE

The EIS discussed in broad terms the need for a quality assurance programme during the siting process. As stated in the EIS, the objectives of the quality assurance (QA) program would be to ensure that all site screening and site evaluation activities achieve the prescribed quality, provide complete documentation and traceability of records, and provide confidence that the data can be reproduced by independent auditors if necessary (Davison et al. 1994).

The Nuclear Waste Management Organization, following a federal government decision on the preferred long-term used fuel management strategy, would be responsible for undertaking the siting process and would have to adopt a quality assurance programme compatible with established international norms (e.g., ISO 9001). Not only must the QA programme ensure that the data gathering procedures followed during siting are consistent and that the results can be interpreted with the highest degree of confidence, but it must help ensure that the logic of the conclusions reached with regard to the conceptual model for a candidate site is traceable and defensible.

References:

Davison, C.C. et al. 1994. The disposal of Canada's nuclear fuel waste: Site screening and site evaluation technology. AECL Research Report 10713.

5.07 Siting - Existence of Suitable Sites

PARTICIPANT COMMENTS

Atomic Energy Control Board

Insufficient evidence is provided to support the statement that technically suitable sites are available.... there is no discussion of the minimum requirements for a disposal facility or the relatively suitability of the various plutonic rock bodies identified. Evidence and reasoned arguments are not provided to support the statement that "the features and processes of importance for groundwater flow and contaminant transport and the range of conditions (such as permeability, porosity, and groundwater chemistry) at the Whiteshell Research Area are not unusual" (EIS, p. 343). [Comment 560, Source Document gov002, Page 15, Section A.2.2]

AECL has not provided reasonable confidence that a mass of rock with a permeability of 10-19 m2 is attainable on the scale of the vault. They have not attempted to demonstrate the existence of such a block at the URL site. AECL does not provide evidence that rock blocks on the order of 4 km2 with permeabilities of 10-19 m2 or lower are common in the Canadian Shield, or that a large rock block with such a low permeability can be adequately characterized. [Comment 563, Source Document gov002, Page 16, Section A.3.1]

Environment Canada

AECL does not demonstrate that plutons occur in the Canadian Shield with the characteristics appropriate for potential repository sites (suitable volume, at the required depth, with low permeability, and with sufficient spacing between major discontinuities). The EIS should show that such blocks of rock are likely to exist. [Comment 897, Source Document gov003, Page 64, Section 3]

Hare, Driedger, Jennekens, Rogers, and Shemilt

Among the subjects of concern are ... assurance that suitable sites exist [Comment 1407, Source Document phpub150, Page 4]

Joint Committee of the Canadian Academy of Engineering and the Royal Society of Canada

We share with SRG and TAC the opinion that suitable sites will be found to exist within the accessible regions of the Canadian Shield. [Comment 1185, Source Document ph3tec001, Page 5]

Northwatch (Lloyd)

Additional Key Information Deficiencies Identified in Phase II Technical Hearings (June 1996) ... - availability and extent of "appropriate" rock formations [Comment 1548, Source Document ph2tec045, Page 24]

OECD/NEA Review Group

The AECL team presented a convincing case for the existence and potential availability of the sparsely fractured rock, supported by a visit to the URL by the Group to examine its properties at first hand. [Comment 1211, Source Document tec001, Page 09, Section 3.2.1]

Scientific Review Group

Field and laboratory evidence suggests that bodies of sparsely fractured, low permeability plutonic rock with the requisite permeability, strength, and size to host a nuclear fuel waste disposal vault may be found in the Canadian Shield in Ontario. This evidence has not been systematically compiled and reviewed in AECL's EIS and supporting reference documents ... and most of it is widely dispersed or unpublished. [Comment 330, Source Document tec004, Page 037, Section 5.5]

The existence of large volumes of essentially unfractured rock has not been demonstrated.... AECL has detailed drill logs from numerous deep boreholes at research areas in the Canadian Shield. However, only one figure shows a drill log from URL with significant intervals of unfractured rock (R-Siting 1994: Figure 6-8, p.137). [Comment 20, Source Document tec004, Page 112, Section A-2.2.3]

The existence of a body of sparsely fractured rock of the requisite size to contain the disposal vault, and with the requisite hydrogeological properties to ensure containment of the nuclear fuel waste contaminants has not been documented in this document; nor has information been given about the tests or evidence that would be used to document its existence. [Comment 237, Source Document tec004, Page 217, Section G-3.1.5]

New information that has been published or presented at the Panel hearings by AECL (Stevenson et al. 1996a; Stevenson et al. 1996b) provides increased confidence that suitable blocks of sparsely fractured rock do exist at the WRA and can potentially be found at other sites. [Comment 902, Source Document tec004a, Page 11, Section 2.5]

The documented occurrence of blocks of low-permeability rock containing old saline groundwater under abnormally high pressure at the WRA gives confidence that suitable blocks having the required characteristics to host a vault can be found in the Canadian Shield. However, the actual existence of a suitable host rock will have to be proven by field exploration at each site under consideration. [Comment 903, Source Document tec004a, Page 12, Section 2.5]

OPG RESPONSE

The Environmental Impact Statement, the Second Case Study and the Third Case Study (in progress) provide evidence that implementation of the repository concept can be achieved in a variety of geosphere settings.

At a high level there are a variety of characteristics which may define a suitable site. As a basis for the concept, the geosphere must offer a stable geomechanical and geochemical environment, as well as act as a deterrent to intrusion. Radionuclide retardation and retention will be governed by site-specific flow system properties that are not known in detail a priori. Site characterisation is tasked with conceptual model(s) development in which multi-disciplinary data are integrated into an internally consistent understanding of flow system properties, geometry and boundary conditions. This conceptual model(s) provides the reasoned basis for performance assessment realizations of the geosphere. It is evident that continued peer review and articulation of conceptual model development is a critical stage in geosphere performance and this has received increased focus in the Deep Geologic Repository Technology Program. Candidate sites at which evidence exists for long-term flow system stability without the intrusion of oxygenated groundwaters to repository horizons may be suitable to host a used fuel repository.

Further work is planned by OPG to address the issue of site availability and to place into context geosphere requirements for implementation of the deep geologic repository concept.

6 ENGINEERING

6.01 Engineering - General

PARTICIPANT COMMENTS

Scientific Review Group

The nature of biological processes and their influences on the movement of radionuclides, as well as the changes with time that may occur during the life of the disposal vault, must be taken into consideration in the design and implementation of the disposal system, especially if they produce maximum exposure scenarios. [Comment 335, Source Document tec004, Page 040, Section 5.6]

the SRG is also of the opinion that the capability and technology exist to engineer an acceptable and achievable robust multiple-engineered barriers system, through choice of different container materials and design, container emplacement method, and a stable vault design. [Comment 28, Source Document tec004, Page 117, Section B-S]

There is little discussion of alternate materials and designs for engineered barriers, validation of the reference choices presented, or evaluation of the physical and chemical properties of alternate materials.... In order to achieve the stated goals for acceptable performance of the disposal concept, namely minimizing uncertainties of environmental impacts and to maximize engineering design benefits, additional details of materials and alternate engineering designs should have been evaluated. [Comment 74, Source Document tec004, Page 135, Section C-2.1.4]

the concept design for a nuclear fuel waste disposal facility, in its present form, is deemed to be unacceptable. [Comment 99, Source Document tec004, Page 141, Section C-3]

OPG RESPONSE

The engineering concept was illustrated for the EIS using a titanium container and in-floor borehole emplacement design . Technical issues with this design were partly overcome in the copper container and in-room emplacement design that AECL prepared and submitted during the public review process for the EIS (Wikjord et al. 1996).

OPG has further advanced the design of a used fuel container and a repository. Additional work has resulted in

the selection of a reference container with a copper corrosion barrier, a steel inner load-bearing vessel and a basket to support the fuel bundles (Maak 1999, Poon et al. 2001, Russell and Simmons 2003). Although the exact dimensions and other details have not been finalized, this container design is very similar to that being considered in the Swedish and Finnish programs. Therefore, the validation of the choice of materials and other factors can also draw on the extensive work undertaken by those programs.

OPG has not selected an emplacement method. Both the in-room and the in-floor borehole emplacement methods are still considered feasible (Russell and Simmons 2003, and a horizontal borehole emplacement concept is also being considered. Again, all these concepts have analogs in other national waste management programs, and can to some extent draw on the information about options, materials and validation from those programs. For example, there is a full-scale prototype repository test of the in-floor geometry at the Swedish Aspo laboratory.

The Canadian program is continuing to evaluate the materials and design. The current studies are described in the Annual Reports (e.g. Gierszewski et al. 2003) and the associated reports.

References:

Gierszewski, P., S. Russell, A. D'Andrea, F. Garisto, M. Jensen, T. Kempe, P. Maak, G. Simmons and A. Vorauer. 2003. Deep Geologic Repository Technology Program - Annual Report 2002. Ontario Power Generation Report, 06819-REP-01200-10100-R00.

Maak, P. 1999. The selection of a corrosion-barrier primary material for used-fuel disposal containers. Ontario Power Generation Report, 06819-REP-01200-10020-R00

Poon, G., M. Saiedfar and P. Maak. 2001. Selection of a primary load-bearing component conceptual design for used-fuel containers. Ontario Power Generation Report 06819-REP-01200-10051-R00

Russell, S.B. and G.R. Simmons. 2003. Engineered barrier systems for a deep geologic repository in Canada.

Proc. 10th International High-Level Radioactive Waste Management Conference, Las Vegas, USA

Wikjord, A.G., P. Baumgartner, L.H. Johnson, F.W. Stanchell, R. Zach and B.W. Goodwin. 1996. The disposal of Canada's nuclear fuel waste: A study of postclosure safety on in-room emplacement of used CANDU

fuel in copper containers in permeable plutonic rock - Volume 1: Summary. Atomic Energy of Canada Limited Report AECL-11494-1, COG-95-552-1.

6.02 Engineering - Container

6.02.01 Engineering - Container - General

PARTICIPANT COMMENTS

Jansen, Ted

There is no evidence that even the most basic design engineering has been done by AECL on the copper containers.... standard design practice has not been followed: you build full size and scaled models, using your prototype production tools, under production conditions, and you test the models to failure. [Comment 1418, Source Document ph3pub111, Page 2]

Joint Committee of the Canadian Academy of Engineering and the Royal Society of Canada

We agree with the SRG and TAC that the engineered container design is safe and effective, provided that the advantages for long-term integrity, such as are demonstrated by the design used in the Second Case Study, are matched by the strength required for safe transportation, handling and emplacement. Continued development and demonstration of container options, derived from the alternatives currently proposed, are needed to answer legitimate public concerns. [Comment 1182, Source Document ph3tec001, Page 4]

Saskatchewan Environmental Society

outline what changes in container thickness and design would be required for copper or titanium containers to achieve a minimum container lifetime objective of (i) 1,000 years (ii) 5, 000 years (iii) 10,000 years. [Comment 1674, Source Document pub040, Page 10, Section 17]

Scientific Review Group

Other materials should have been considered more closely and detailed comparisons should have been made [Comment 347, Source Document tec004, Page 045, Section 6.2.1]

Alternate materials such as copper or nickel, an alternate design using thick container walls, and different designs for internal support to resist hydrostatic stress are not discussed. [Comment 89, Source Document tec004, Page 138, Section C-2.2.1]

OPG RESPONSE

As a result of additional studies (e.g. Baumgartner and Ates 2001, Maak and Simmons 2001), OPG has selected a reference container with a copper corrosion barrier, a steel inner load-bearing vessel, and a basket to support the fuel bundles (Maak 1999, Poon et al. 2001, Russell and Simmons 2003). Although the exact dimensions and other details have not been finalized, this container design is very similar to that being considered in the Swedish and Finnish programs. Therefore, the further development of the container can also draw on the extensive work undertaken by these programs (e.g., Wu et al. 2000).

References:

Baumgartner, P. and Y. Ates. 2001. Packaging plant and repository factors affecting the selection of preferred used-fuel container geometries and capacities. Ontario Power Generation, Nuclear Waste Management Division Report 06819-REP-01200-10064-R00. Toronto, Canada.

Maak, P. 1999. The selection of a corrosion-barrier primary material for used-fuel disposal containers. Ontario Power Generation Report, 06819-REP-01200-10020-R00

Maak, P. and G.R. Simmons. 2001. Summary report: A screening study of used-fuel container geometric designs and emplacement methods for a deep geologic repository. Ontario Power Generation, Nuclear Waste Management Division Report 06819-REP-01200-10065-R00. Toronto, Canada.

Poon, G., M. Saiedfar and P. Maak. 2001. Selection of a primary load-bearing component conceptual design for used-fuel containers. Ontario Power Generation Report 06819-REP-01200-10051-R00

Russell, S.B. and G.R. Simmons. 2003. Engineered barrier systems for a deep geologic repository in Canada. Proc. 10th International High-Level Radioactive Waste Management Conference, Las Vegas, USA.

Wu et al. 2000. Inspection of copper canisters for spent nuclear fuel by means of ultrasound, SKB Report TR-00-23. Stockholm, Sweden.

6.02.02 Engineering - Container - Designs for Longer Lifetimes PARTICIPANT COMMENTS

[Comment 2161, Source Document , Page]

Saskatchewan Environmental Society

The disposal plan must be designed around a time frame objective that truly protects future generations. In our view, future generations should be assured that high level nuclear waste will be completely isolated from the environment for a period of at least 10,000 years. [Comment 1677, Source Document phpub094, Page 2]

OPG RESPONSE

OPG has defined a preliminary design requirement for used fuel container lifetime of not less than 100,000 years (Russell and Simmons 2003). The present reference Canadian concept, with copper shell on a steel inner vessel, is expected to meet this requirement. This is consistent with the predicted lifetimes of the similar Swedish and Finnish containers for a deep geologic repository.

Reference:

Russell, S.B. and G.R. Simmons. 2003. Engineered barrier systems for a deep geologic repository in Canada. Proc. 10th International High-Level Radioactive Waste Management Conference, Las Vegas, USA.

6.02.03 Engineering - Container - Fabrication

6.02.03.01 Engineering - Container - Fabrication - Methodology PARTICIPANT COMMENTS

Natural Resources Canada

It should also be remembered in subsequent considerations of degradation by stress corrosion cracking that closure welds, unless stress relieved, can generate residual stresses in the containers which approach the yield strength of the material. [Comment 757, Source Document ph2gov001, Page bar3]

it is not clear at this time that the integrity of the electron-beam weld which closes the container can be verified by non-destructive evaluation (NDE) with the same degree of certainty.... steel-liner support of the copper container increases the probability of sound welds relative to packed-particle support and, in our opinion, electron beam welding (which must be done in a vacuum of 0.7Pa or better) may not be feasible with a copper-shell packed-particle design.... we recommend that: 1) the size and frequency of defects in actual electron beam closure welds should be established by destructive metallurgical evaluation; 2) a redesign of the copper container should be considered to shorten the closure weld and thereby reduce the frequency of defects in each container; and that 3) the particulate-support design option should not be pursued if electron-beam welding is used for the closure weld. [Comment 826, Source Document ph2gov015, Page 09]

OPG RESPONSE

OPG is aware of the potential for residual stresses in the containers and has developed preliminary design requirements to address this issue. The present reference design uses an inner steel vessel for structural support, rather than a packed-particulate support (Russell and Simmons 2003). In a recent study, a preliminary structural analyses of used fuel containers found that the external surface of the electron-beam weld closure would be subjected to compressive stresses, which would minimise the risk of the initiation and propagation of stress-corrosion cracking of the container (Saiedfar and Maak 2002).

The potential for stress corrosion cracking of the copper outer corrosion barrier material is being addressed in the technical work program at OPG (and the Swedish and Finnish programs) (e.g., Gierszewski et al. 2003).

References:

Gierszewski, P., S. Russell, A. D'Andrea, F. Garisto, M. Jensen, T. Kempe, P. Maak, G. Simmons and A. Vorauer. 2003. Deep Geologic Repository Technology Program - Annual Report 2002. Ontario Power Generation Report, 06819-REP-01200-10100-R00.

Russell, S.B. and G.R. Simmons. 2003. Engineered barrier systems for a deep geologic repository in Canada. Proc. 10th International High-Level Radioactive Waste Management Conference, Las Vegas, USA.

Saiedfar, M. and P. Maak. 2002. Preliminary assessment of the deformation and stresses of copper used-fuel containers in a hypothetical deep geologic repository. Ontario Power Generation Report 06819-REP-01300-10049-R00.

6.02.03.02 Engineering - Container - Fabrication - Decontamination PARTICIPANT COMMENTS

Scientific Review Group

Unless AECL has new fabrication techniques and tools, most of the operations described involve tool steels. It is certainly true that iron contamination is a potential corrosion problem for titanium. However, it would probably be more appropriate to discuss decontamination of any potential iron particles. [Comment 90, Source Document tec004, Page 138, Section C-2.2.1]

OPG RESPONSE

OPG has reviewed the options for corrosion barrier material for used fuel containers in a deep geologic repository (Maak 1999). The study examined a number a candidate corrosion-barrier materials (e.g., titanium, copper, steel, nickel) and commissioned an international peer review of the report findings. The study recommended the use of high-purity copper. This is the same material selected for the Swedish and Finnish programs.

Therefore, technical issues associated with titanium are no longer applicable.

References:

Maak, P. 1999. Selection of a corrosion-barrier primary material for used-fuel disposal containers. Ontario Power Generation Report 06819-REP-01200-10020-R00.

6.02.03.03 Engineering - Container - Fabrication - Inspection PARTICIPANT COMMENTS

Natural Resources Canada

In the case of copper container (thickness of 25 mm), nondestructive evaluation of electron-beam welds will be difficult if not impossible.... when the grain size is 0.1 times the wavelength or greater, excessive scattering may make it impossible to conduct valid ultrasonic inspections.... the feasibility of helium leak detection techniques as a back-up system are not clear. [Comment 756, Source Document ph2gov001, Page bar3]

it is not clear at this time that the integrity of the electron-beam weld which closes the [copper] container can be verified by non-destructive evaluation ... Indeed, both ultrasonics and helium leak detection may prove to be problematic in this application. [Comment 792, Source Document ph2gov001a, Page 05, Section 2.1]

Northwatch and Campaign for Nuclear Phaseout (Kreusch, Neumann, and Gruppe Ekologie)

An electron-beam welded joint is mainly expected to have defects in the form of pores. Also larger defects are possible which cannot be detected by non-destructive inspection. [Comment 1580, Source Document ph2tec044, Page 07, Section 3]

Scientific Review Group

Ultrasonic inspection of composite structures has proved to be a difficult technique to arrive at unequivocal results. For example, defects that are in the plane of the sonic wave are very difficult to detect. ... the technique ... would have to undergo extensive qualification to ensure both equipment reliability and operator competence. ... small, sub-critical defects that may grow by hydrogen embrittlement or cracking may be difficult to detect in titanium. [Comment 91, Source Document tec004, Page 138, Section C-2.2.1]

OPG RESPONSE

OPG recognises that non-destructive evaluation of electron-beam welded copper containers would be challenging. However, studies and tests are being carried out by other countries to address this issue. In particular, there is a substantive effort to develop fabrication and testing methods for similar copper containers in Sweden and Finland (e.g., Wu et al. 2000). Alternative techniques for fabrication are also under consideration. OPG considers non-destructive evaluation of the welded copper containers to be a resolvable issue.

References

Wu et al. 2000. Inspection of copper canisters for spent nuclear fuel by means of ultrasound. SKB Report TR-00-23. Stockholm, Sweden.

6.02.04 Engineering - Container - Loading

PARTICIPANT COMMENTS

Natural Resources Canada

It is not clear ... if or how the bundles will be selected so that each container will enclose fuel of the "average" burnup level, thereby avoiding exceptionally hot containers and hot spots in the vault. [Comment 754, Source Document ph2gov001, Page bar2]

Risk Assessment Society

Methods of on-site packaging are not fully explained. Is it possible that packaging and sealing could be carried out at an earlier stage? [Comment 1420, Source Document pub021, Page 2]

Scientific Review Group

The discharge burn-up value of nuclear fuel waste selected for modelling purposes has been quoted at 685 GJ/Kg U. This value has been used by AECL to assess radionuclide content and radioactive heat production of the fuel waste bundles (R-Barriers 1994: p.11). Actual burn-up rates for typical fuel waste bundles have been shown to be as high as 1100 GJ/Kg U (R-Barriers 1994: Fig 2.3, p.12), and for product material originating from the Bruce generating station to average 825 GJ/Kg U (R-Barriers 1994: Fig. 2-3, p.12). This discrepancy, which involves significantly higher heat production in the fuel waste than is specified in the reference design, could adversely affect the performance of the barriers that are defined by the reference design. Higher burn-up values would result in higher thermomechanical stresses on containers, and would adversely affect the performance of clay seals [Comment 519, Source Document tec004, Page 044, Section 6.2.1]

OPG RESPONSE

OPG has a database which identifies the burnup and age of a used fuel bundle. The used fuel bundles loaded in a container would be selected to ensure that the total heat loading of the container met the repository thermal design limits. Furthermore, since the reference container design holds about 300 bundles, it would be unlikely that a large fraction of the bundles would accidentally be high thermal power. Finally, it is likely that monitoring methods could be incorporated into the packaging plant design as a final check if appropriate (e.g. possibly based on the gamma output).

Early packaging and sealing might be considered as an option to allow off-site packaging and/or a period of surface storage before disposal in a repository. However, a container intended for surface storage or transportation conditions would be optimized differently than one intended for deep geologic repository conditions. The present reference container design emphasizes durability under repository conditions; it has been designed to withstand the expected external pressure loads in a DGR and the handling load in the packaging plant and during emplacement operation in the repository.

6.03 Engineering - Excavations

6.03.01 Engineering - Excavations - Design Criteria

PARTICIPANT COMMENTS

Campaign for Nuclear Phaseout

With regard to the parameters of nominal excavation, why were 500 metres to 1000 metres established as excavation parameters? There is no explanation as to how these figures were arrived at. [Comment 1804, Source Document pub027, Page 26, Section III.E]

Canadian Coalition for Ecology, Ethics and Religion

would it be technically feasible to build the vault at a depth well below that of ground water which discharges to the surface or could be accessed through drilled wells? [Comment 1841, Source Document phpub043, Page 35, Section 13]

Natural Resources Canada

The engineering basis for adopting the 25% extraction rate requires further clarification as to whether it involves an areal or volumetric extraction. While this rate is a conservative extraction rate in mining terms, the engineering justification for its acceptance is warranted; lowering the extraction rate and the resultant reduction in the induced stress would benefit the overall design. [Comment 800, Source Document ph2gov001a, Page 08, Section 2.2.2]

This analysis does suggest that a suitable combination of vault-depth/tunnel-aspect-ratio could be chosen, but it would a) require revision once the particular site was chosen and its stress state and rock quality determined, and b) be unlikely to be found for depths outside the range 300 m to 1000 m. [Comment 830, Source Document ph2gov015, Page 16]

Scientific Review Group

The vault design criterion uses a strength-to-stress ratio of two to one for the rock webs between the emplacement boreholes and rooms. Standard mining practice, which is concerned with short-term stability, assumes certain failure of mines if the ratio is three or less. Consequently, a ratio of three or higher will have to be established if vault stability is to be assured, particularly given the long periods anticipated for operation of this facility during loading of waste, and the requirement of long-term stability after closure of the facility (R-Barriers 1994: p.191). [Comment 59, Source Document tec004, Page 127, Section B-2.2.4]

in the Canadian Shield, the major stress direction is horizontal. Vault stability will, therefore, be controlled by the horizontal stress ratio and not by the extraction ratio. There is not sufficient flexibility in the vault design, e.g. the use of in-room placement, varying the vault depth below the surface, etc. to achieve a higher strength to stress ratio of the rock mass after excavation. [Comment 61, Source Document tec004, Page 127, Section B-2.2.4]

OPG RESPONSE

A repository depth range of about 500 to 1000 meters is consistent with the range of depths being considered by other countries (e.g., Finland and SKB). It is considered to be deep enough to avoid the possibility of surface conditions (e.g., climate change, glaciation) directly affecting the repository, and deep enough to minimise the risk of human intrusion. In the Canadian Shield, at depths below about 500 m, the groundwater is saline.. This salinity is an indication that the deep groundwaters are old and not readily discharging to the surface. Furthermore, the water would be undrinkable. For this and other reasons (ready availability of potable water at shallower depths), wells would not be drilled to repository depths.

At greater depths, the ambient rock temperature, overall stresses and groundwater salinity increase, making the repository design more difficult.

In the Canadian Shield, and particularly in volumes of sparsely fractured rock that exhibit very high horizontal stress relative to the vertical stress, the emplacement room and the in-floor borehole emplacement holes could be subject to localised stress concentrations that may lead to instabilities at the excavation perimeters. However, this stress anisotropy decreases with depth of the repository.

It is expected that stable rock openings could be constructed for both the in-room and in-floor emplacement methods. Stable excavations in highly-stressed rock on the Canadian Shield have been demonstrated at AECL's Underground Research Laboratory (e.g. Read and Chandler 2002).

The detailed design of a repository would be done in the context of a specific site. The repository depth (or depth range), extraction ratio and other design factors will be developed in the context of the specific site characteristics and rock mass properties.

Reference:

Read, R.S. and N. A. Chandler. 2002. An approach to excavation design for a nuclear fuel waste repository - the thermal mechanical stability study final report. Ontario Power Generation Report 06189-REP-01200-10086-R01.

6.03.02 Engineering - Excavations - Layout

PARTICIPANT COMMENTS

Durham Wetlands and Watersheds

More spacing is needed between the boreholes in the concept and the rooms would be better divided into subvaults. [Comment 2006, Source Document pub043, Page 5]

Joint Committee of the Canadian Academy of Engineering and the Royal Society of Canada

the scheme of bypassing flows may have merit in local areas (as a possible alternative to use of sealing measures) depending on actual geological and hydrogeological conditions present at the selected site. This method, based on use of a pervious surround, has been accepted for use for disposal of uranium tailings below the water table in a disused open pit mine at Rabbit Lake, Saskatchewan. It is suggested that AECL carry the groundwater by-pass method as a possible expedient for use in local areas, if merited, depending on the results of detailed design studies. [Comment 1160, Source Document ph2tec007, Page 07]

Since no site can be guaranteed to be perfectly impermeable forever, techniques of bypassing flow around the site (hydraulic cage concept) deserve comprehensive consideration (.Re.f. .3). [Comment 1144, Source Document tec003, Page w02, Section 3]

Natural Resources Canada

In general terms, the vault design is simple and efficient. However, various options, -- two levels versus single level; room, pillar or floor alternatives -- are mentioned but not compared. We recommend that such a comparison be made. [Comment 799, Source Document ph2gov001a, Page 07, Section 2.2.2]

Northwatch (Lloyd)

Deficiencies Which Emerged or Remain Outstanding After Discussion in the Phase II Tehncial Hearing Sessions ...

-determination of extent or minimum/maximum size [Comment 1534, Source Document ph2tec045, Page 22]

Science for Peace (Energy Working Group)

we suggest a random location of the emplacements in a large three-dimensional region within the plutonic rock. In a random cluster repository any fracture and shifting of the host rock may damage some of the containers, but not so many or even all as in the case of a plane repository. Thus, the random three-dimensional cluster repository reduces the risk of major releases radioactive material into the environment. [Comment 1721, Source Document ph2pub034, Page 6]

Scientific Review Group

A critical discussion of alternative vault designs, in light of the in situ, excavation-induced, and thermomechanical stress fields, and the potential for fracturing, would have been desirable. [Comment 367, Source Document tec004, Page 051, Section 6.2.3]

R-Siting does not explain or provide an example of how the geotechnical information gathered during site investigations could be used to design a disposal vault and vault layout, and what different conditions might result in changes in design. [Comment 19, Source Document tec004, Page 111, Section A-2.2.2]

There is almost exclusive focus on a room-and-pillar excavation layout, to the exclusion of other designs for underground excavations... Justification should have been made by AECL for adhering to the decade old design, and for reasons why continuous upgrading has neither been accommodated nor acknowledged. [Comment 71, Source Document tec004, Page 134, Section C-2.1.1]

OPG RESPONSE

AECL has completed conceptual design/feasibility studies of various repository design concepts (see Baumgartner and Simmons 1987, Simmons and Baumgartner 1994, Baumgartner et al. 1996). These studies include some discussion of the advantages and disadvantages of each design alternative. However, this work is dated and would be repeated prior to or as part of the detailed repository design for a specific site.

Presently, OPG is considering various emplacement concepts and repository layouts; all similar to concepts presently under detailed consideration by other countries (e.g. Russell and Simmons 2003). The details of the repository design include the spatial arrangement of emplacement rooms, the spacing between individual containers, and the location of these within the rock mass. Non site-specific designs can only address these issues in a general way.

OPG has conducted a number of thermal and mechanical studies to support the design of a deep geologic repository for used fuel, including the spacing of containers in boreholes or in rooms. For example, after reviewing the throughput of nuclear fuel in Canadian reactors and given the earliest inservice date of 2035 for a geologic repository, the reference fuel age has been increased to 30 years (AECL used 10 years). This affects the container thermal output, and therefore the vault layout.

Also, in 2001, OPG initiated a screening study of used fuel container geometries, capacities and layout in the vault for both in-room and in-floor borehole emplacement methods. AECL's reference used fuel container had a capacity for 72 fuel bundles. The screening study recommended larger used fuel containers (Baumgartner and Ates 2001; Maak and Simmons 2001). Currently, OPG's reference container has a capacity for 324 bundles (similar in size and mass to the container designs in Sweden and Finland) (Russell and Simmons 2003). The spacing of containers in the vault has therefore increased compared to AECL's 1994 layout to ensure that the container temperature remains below the thermal design limit of 100°C and to minimise rock breakout in the borehole.

The detailed design of a deep geologic repository for used fuel is a site-specific issue. The design process would consider the feasibility and safety of all practical designs, including the "hydraulic cage" design. However the hydraulic cage is not applicable in all geosphere conditions, for example, it would not be useful if the repository were located in a rock mass where diffusion is the dominant transport mechanism, for example in the sparsely-fractured rock mass of the 1994 EIS Case Study by AECL.

References:

Baumgartner, P. and Y. Ates. 2001. Packaging plant and repository factors affecting the selection of preferred used-fuel container geometries and capacities. Prepared by Atomic Energy of Canada Limited. Ontario Power Generation Report 06819-REP-01200-10064-R00.

Baumgartner, P. and G.R. Simmons. 1987. Disposal centre engineering for the Canadian Nuclear Fuel Waste Management Program. Radioactive Waste Management and the Nuclear Fuel Cycle 8, 219-239.

D.M. Bilinsky, Y. Ates, R.S. Read, J.A.L. Crosthwaite and D.A. Dixon. 1996. Engineering for a disposal facility using the in-room emplacement method. Atomic Energy of Canada Limited Report AECL 11595, COG-96-223.

Maak, P. and G.R. Simmons. 2001. Summary report: A screening study of used-fuel container geometric designs and emplacement methods for a deep geologic repository. Ontario Power Generation Report 06819-REP-01200-10065-R00.

Russell, S.B. and G.R. Simmons. 2003. Engineered barrier systems for a deep geologic repository in Canada. Proc. 10th International High-Level Radioactive Waste Management Conference, Las Vegas, USA.

Simmons, G.R. and P. Baumgartner. 1994. The disposal of Canada's nuclear fuel waste: Engineering for a disposal facility. Atomic Energy of Canada Limited Report AECL-10715, COG-93-5.

6.03.03 Engineering - Excavations - Methods

PARTICIPANT COMMENTS

Joint Committee of the Canadian Academy of Engineering and the Royal Society of Canada

Boring techniques are improving and we can envisage an excavation program involving road headers for the rooms and a TBM for the longer tunnel drives, particularly for a specific site that would allow long drives. [Comment 1172, Source Document ph2tec010, Page 12, Section H.3]

Northwatch and Saskatchewan Environmental Society (Richardson)

The fact that much of the work at the URL has been carried out in 'sparsely-fractured rock' also makes it important that AECL too develops a methodology for passing through major flowing zones, which cannot at this stage be ruled out from existing at a potential candidate site. [Comment 1596, Source Document ph2tec037, Page 14, Section 4.2]

OPG RESPONSE

In preparing the Environmental Impact Statement, AECL chose repository engineering and construction methods that were proven to be applicable in the range of environments that could be encountered in the Canadian Shield. At that time, only the drill-and-blast method of construction provided the flexibility necessary to construct the repository arrangement. AECL did consider using either the pilot-and-slash or the full-face drill-and-blast excavation method (Simmons and Baumgartner 1994). The Swedish program has examined excavating using the drill-and-blast method and a Tunnel Boring Machine at SKB's Aspo Hard Rock Laboratory.

Both excavation methods have been used to create opening in poor quality, water-bearing zones in rock masses. If this situation were to be encountered at a repository site, engineering methods exist to prepare the location and to excavate through such zones (e.g., excavation through fracture zones during the development of the ramp access to the SKB Aspo Hard Rock Laboratory, excavation of the shaft of AECL's UndergroundResearch Laboratory through Fracture Zones 3, 2.5 and 2).

Both excavation methods are feasible and the method chosen at a specific repository site will depend on a number of site-specific conditions, the details of the repository design (e.g., the length, orientation and shape of tunnels and rooms) and the technical feasibility and cost of these methods at the time of construction (likely many years from now).

References

Simmons, G. and P. Baumgartner. 1994. The disposal of Canada's nuclear fuel waste: Engineering for a disposal facility. Atomic Energy of Canada Limited AECL-10715, COG-93-5.

6.03.04 Engineering - Excavations - Access

PARTICIPANT COMMENTS

Risk Assessment Society

While it is apparent that much research has been applied to [materials handling], we have concern that it may have been developed in isolation (i.e. insufficient liaison with the Canadian mining industry which has considerable expertise in the design and operation of shafts and hoists. There is need to explain the provision of fail/safe mechanisms in shafts. Has the multi-compartment shaft been considered, allowing easier access in emergency, and in providing counter-balanced "skips". Has the possibility of inclined shafts been considered? [Comment 1419, Source Document pub021, Page 2]

OPG RESPONSE

AECL pointed out in R-Facility (see Simmons and Baumgartner 1994) that Canadian mining industry practice was proposed for the design, equipping and operation of shafts (Section 4.3.1, page 174). The single compartment and multi-compartment shafts with friction hoists (some using counterweights and some using balanced skips) were described and the safety mechanisms on the hoists were outlined.

OPG is investigating both ramp and shaft access to a deep geologic repository. Posiva (Finland) and SKB (Sweden) are also considering both options in their repository designs. The specific design of each repository access system would be done as part of the detailed repository design in the context of a detailed safety and risk analyses at the appropriate stage of development, for example, at the specific site. This level of detailed work is not anticipated to be required until the site selection phase of the program.

References:

Simmons, G.R. and P. Baumgartner. 1994. The disposal of Canada's nuclear fuel waste: engineering for a disposal facility, AECL-10715, COG-93-5.

6.04 Engineering - Seals

6.04.01 Engineering - Seals - Properties

PARTICIPANT COMMENTS

Science for Peace (Energy Working Group)

The buffers and the backfill material should be water repellent, non-corrosive and plastic material. Under the pressure from upper layers the plastic material will enter into any old or new cracks in the host rock and prevent water circulation in the repository. Thus the water repellent, plastic material will give the repository a self-healing property.... consideration should be given to a water rejecting material such as tar sand from Alberta. Tar is a non-corrosive, reducing, rather than oxidizing material. Even radiative will produce carbon and hydrogen that will further reduce the oxygen concentration in the buffer. Unlike clay, tar is water repellent material that will deflect water and not be washed away easily by fast groundwater currents. [Comment 1722, Source Document ph2pub034, Page 7]

Rigid and immobile concrete plugs would prevent the flow of the viscous backfill material, and would prevent the self-healing of the repository. Therefore, rigid plugs should not be placed in the repository [Comment 1723, Source Document ph2pub034, Page 7]

Scientific Review Group

The relative swelling pressures of different clay based sealing materials is not adequately evaluated... For similar density levels, the Canadian Avonseal bentonite and bentonite-sand mixtures exhibit noticeably lower swelling pressure response than Wyoming bentonites. In terms of ensuring adequate sealing capacity within vaults, a clay material that is capable of exhibiting low hydraulic response and low swell pressure would be more suitable. [Comment 39, Source Document tec004, Page 122, Section B-2.1.12]

No mechanical properties, such as shear strength, or compressibility, of the buffer material were presented for calculation of bearing capacity and settlement [Comment 515, Source Document tec004, Page 126, Section B-2.2.3]

The properties of the sealing materials, including the buffer and backfill components, have not been sufficiently evaluated, and subjected to appropriate quality control procedures. The assessment of the role and effectiveness of the sealing materials is too optimistic [Comment 64, Source Document tec004, Page 128, Section B-2.2.5]

The properties of the aggregate clay and sand or gravel combinations are not defined adequately.... In view of the fact that differences in swell pressures have been shown to exist between clay materials of different types, at similar densities, verification of any stated assumptions should have been attempted and quantifiable results should have been presented. [Comment 65, Source Document tec004, Page 128, Section B-2.2.5]

OPG RESPONSE

Clay-based materials meet the requirements for being impermeable to water, non-corrosive, plastic, and have proven durability on time scales of millions of years. Sufficiently dense clays also should be able to prevent significant microbial activity around the container for a long time. As a general principle, the amount of organic material in the repository is minimized to avoid microbial activity and gas generation. Presently, no radioactive waste management organisation is considering the use of tar (e.g., bitumen) as buffer/backfill in a used-fuel repository. In the absence of a clear advantage to tars, it would not be prudent for the Canadian program to take on the entire task of investigating and validating a new material.

OPG has prepared preliminary design requirements for repository sealing systems. Using these draft requirements for guidance, OPG has initiated a program in repository seal engineering to define the

issues and then develop the material properties and methods necessary to design effective repository seals (e.g., Read and Chandler 2002). As part of the siting of a geological repository, the sealing systems would be demonstrated and detailed safety and performance assessments of repository seals would be conducted.

References:

Read, R.S. and N.A. Chandler. 2002. Development and integration of tools for engineering design of repository sealing systems (ENDRES) project status - March 2002. Ontario Power Generation, Nuclear Waste Management Division Report 06819-REP-01300-10051-R00. Toronto, Canada.

6.04.02 Engineering - Seals - Additives

PARTICIPANT COMMENTS

Northwatch and Campaign for Nuclear Phaseout (Kreusch, Neumann, and Gruppe Ekologie)

Relatively large quantities of oxygen become entrapped in the pores in the buffer material when the final repository is sealed ... In this connection it could be questioned whether AECL did made reflections about additions to the buffer mixture for reducing the content of oxygen, for example ferrosphosphate. [Comment 1581, Source Document ph2tec044, Page 08, Section 3]

People Against Lepreau 2

We request the proponent be instructed to explore the option forwarded by the USGS hydrologists dealing with the inevitable leak or criticality by chemically fixing the mobile uranophile elements in the surrounding media as a mineral complex.... the proponent should study the impact of introducing phosphates or graphite into the negatively charged bentonite or clays surrounding the canisters.... Graphite and phosphates act as a stabilizing sponge to chemically attractive uranium based mineral complexes. [Comment 1638, Source Document pub018, Page 3]

Robertson, J.A.L.

The analysis in the EIS clearly shows that iodine-129 will be the critical nuclide with respect to the estimated mean dose rate and consequent risk (see, for instance, AECL-10711, Figure 7-9). I would therefore expect there to be some discussion of how the release of iodine-129 might be controlled, but I have failed to find any in the EIS.... For instance, has the possibility been examined of incorporating natural iodine in the packed particulate around the fuel bundles, or in the buffer material, so that it would leach out at about the same rate as the iodine-129 and dilute it? Would this reduce human and animal uptake of the radionuclide? [Comment 1456, Source Document phpub004, Page 26]

OPG RESPONSE

The addition of several possible chemical additives to the repository has been considered. However, given the long time scales of interest, it is generally thought to be better to keep the design and materials simple and robust.

With respect to the trapped oxygen in the repository, various calculations to date in both the Canadian and other programs have determined that this oxygen is limited in quantity and will be consumed reasonably quickly by various natural processes, even without additives.

With respect to graphite, it has been considered as an additive, but primarily for purposes of improving the thermal conductivity of the clay buffer. Phosphates would be a concern because formation of aqueous phosphate complexes increases the solubility of UO2. Remediation sites where the use of phosphates is being studied are near the surface, i.e., oxidizing conditions prevail and U solubilities are large whereas, for the repository, reducing conditions prevail so U solubilities are expected to be low. More generally, clays are naturally quite sorbing to transuranic elements, so there is little to be gained by chemical additives, whereas such additives would raise questions about the clay chemical behavior at long times that could be complex to address.

The possibility of adding stable iodine to dilute any released I-129 has been considered. The main question is whether the added stable iodine would be available at the time the I-129 was released. Since the I-129 is within the fuel, it is released as the fuel elements are degraded. Stable iodine added to the buffer or into the container would be in a different form and therefore would be dissolved and transported away on a different time scale, and so is unlikely to be available to significantly dilute the I 129. Safety assessment models estimate the time of release of I-129 by conservatively neglecting any effect of the zirconium cladding in delaying fuel contact with groundwater in a failed container, but this would have to be predicted in order to design a suitable stable iodine form, that is sufficiently

soluble to dilute the released I-129 but not so soluble that it is transported away before I-129 releases from the fuel have peaked.

6.04.03 Engineering - Seals - Emplacement

PARTICIPANT COMMENTS

Joint Committee of the Canadian Academy of Engineering and the Royal Society of Canada

The buffers constitute the first line of defence against contaminant leakage beyond the container and it is essential that they be complete and without voids or leakage paths. We, therefore, favour a swelling medium for the buffers and consider that a bentonite-sand mix would seem best suited for such use. Careful placing of the mix is important and efforts must be made to prevent shrinkage of the mix at any time. [Comment 1169, Source Document ph2tec010, Page 10, Section G3]

Care must be taken to ensure that where rooms and tunnels are to be backfilled, the entire space is, in fact, filled and with a clay-sand mix this might require concrete bulkheads so spaced that the last amounts of clay-sand mix or grout can be injected under some pressure. [Comment 1170, Source Document ph2tec010, Page 10, Section G4]

It is important that plugs be keyed to the surrounding rock either by the rough excavated rock surface or by slots cut in the rock. It is also important that concrete plugs are cast against rock surfaces that are clean and free of loose rock. The concrete-rock interfaces of all plugs must be grouted under high pressures to ensure tight contacts. The use of expanding cements for the closing concrete pours should be considered for the additional tightening effect they might contribute. [Comment 1171, Source Document ph2tec010, Page 11, Section G.5]

Planetary Association for Clean Energy

Two alternatives for emplacement of buffer have been investigated: a) compacting the materials in place. b) using precompacted block. We suggest that the first one is better because the hydraulic conductivity of bentonite (main component of the buffer can be decreased by increasing its density through compacting).... We are afraid that between precompacted block the hydraulic conductivity would be high and for this reason, the buffer and backfill barrier would weaken and several radionuclides might reach the low permeability rock. [Comment 1646, Source Document pub029, Page 03]

Saskatchewan Environmental Society

There is a lack of clarity in the description of the composition and production of the buffer blocks.... must some moisture be added to allow the compaction? [Comment 1696, Source Document ph2tec039, Page 5]

OPG RESPONSE

OPG and other countries are continuing to study the features of potential buffer materials and emplacement techniques. OPG is also developing specific

design requirements for repository sealing systems and will use these requirements in establishing the specifications for preparation and placement of the components of these sealing systems

Since the Environmental Impact Statement, there have been a variety of laboratory-scale and fullscale tests of buffer emplacement, including the Tunnel Sealing Experiment at AECL's Underground Research Laboratory, and the Prototype Repository at the SKB Aspo Hard Rock Laboratory. Similar tests are continuing, and eventually, as part of the construction of a geological repository, the sealing systems would be demonstrated.

With respect to fabrication of buffer blocks or pebbles, there is an appropriate amount of moisture that needs to be present during compaction depending on the desired final characteristics of the block, notably its density (e.g. Pusch 2001).
References

Pusch, R. 2001. The buffer and backfill handbook. Part 2: Materials and techniques. SKB Technical Report TR-02-12. Stockholm, Sweden.

6.04.04 Engineering - Seals - Performance Criteria

PARTICIPANT COMMENTS

Atomic Energy Control Board

Performance criteria for the vault seals, in particular strength, interfacial adhesion and the time period of concern, are not stated clearly. [Comment 602, Source Document gov002, Page 41, Section C.1.1(iii)]

Environment Canada

there is no clear statement of the performance objectives which must be met by the overall sealing systems themselves. Sealing system performance objectives should be related specifically to the results of post-closure performance assessment analyses. [Comment 844, Source Document gov003, Page 14, Section 2.5]

There is neither a stated performance requirement for the sealing system across the excavation damage zone nor a well-demonstrated method of providing any specified level of seal efficiency. Therefore, there is considerable uncertainty both as to how effectively the excavation damage zone can be sealed (because of injection difficulties in low-permeability rock), and whether or not seal efficiency has a significant impact on containment. [Comment 845, Source Document gov003, Page 14, Section 2.5]

OPG RESPONSE

OPG has prepared preliminary design requirements for repository sealing systems. Using these requirements as the basis, OPG has initiated a program in

repository seal engineering to define the issues and then develop the material properties and methods necessary to design effective repository seals (e.g. Read and Chandler 2002).

The Tunnel Sealing Experiment at AECL's Underground Research Laboratory will demonstrate the ability of both clay and concrete based room plugs to effectively seal off the excavation damage zone.

References:

Read, R.S. and N.A. Chandler. 2002. Development and integration of tools for engineering design of repository sealing systems (ENDRES) project status - March 2002. Ontario Power Generation, Nuclear Waste Management Division Report 06819-REP-01300-10051-R00.

6.05 Engineering - Managed Flooding

PARTICIPANT COMMENTS

Scientific Review Group

There is no detailed discussion of the potential advantages or disadvantages of flooding (saturation) of the rooms... There would appear to be advantages of a critical evaluation of this managed flooding ... (1) A more reliable (uniform) thermal sink; (2) More rapid shift to a reducing environment, particularly for the case of containers being shielded to the point that radiation fields do not extend beyond the container wall, and hence radiolysis of water is trivial; (3) Reduced microbial activity focused around redox fronts associated with a vacillating water table as the rooms slowly saturate; (4) Greater surface areas exposed at the water-solid interfaces for the sorption of chemicals of concern. The Swedish concept considers interaction of radionuclides with rock surfaces as being of prime interest, but that considerable sorption will also occur into the buffer and clays; (5) Possible collapse of vault room roofs from settling of dry, pneumatically emplaced upper backfill would be avoided; and (6) Self-sealing of fractures in the concrete sealing material would be more likely to occur. [Comment 81, Source Document tec004, Page 137, Section C-2.1.6]

OPG RESPONSE

The need for "flooding" or artificially providing groundwater to the vault sealing materials to ensure rapid saturation of the materials (e.g., bentonite buffer) has not been evaluated in detail. Possible advantages of not flooding are that dry buffer around the container would minimize microbialactivity at the container surface, and also would make retrieval easier. The interaction of thermal-hydraulic-mechanical processes makes evaluating the benefits of flooding complicated. Suitable models are becoming available to address these questions, and are being incorporated into the Canadian program. To some extent, it is also a site-specific issue that would ultimately need to be addressed at a later stage of repository design.

References:

SKB. 2001. RD&D Programme 2001. Programme for research, development and demonstration of methods for the management and disposal of nuclear waste. SKB Report TR-01-30.

6.06 Engineering - Monitoring

6.06.01 Engineering - Monitoring - General

PARTICIPANT COMMENTS

Catholic Women's League of Canada

How will the containers be monitored after burial? Is it possible they could be forgotten... out of sight, out of mind? Who will know if the contents leak and contaminate the drinking water of unsuspecting communities hundred or thousands of miles away? [Comment 1923, Source Document ph3pub009, Page 3]

I am concerned about the leakage, radiation and health hazards which could result from below ground storage that is not completely monitored. [Comment 1926, Source Document ph3pub147, Page 1]

Earth Resources Society of Elliot Lake (Krauss and Dube)

Assuming that deep vault disposal is the advisable course of action, the public would like to know more about planned monitoring programs, such as methods, assigned responsibilities, overseeing groups, alarm systems, and public reporting systems. [Comment 2023, Source Document pub002, Page 10, Section 6]

Monitoring the disposal site by an independent agency was also favoured by (55%) of the participants. [Comment 2028, Source Document pub002, Page 21, Section D]

Health Canada

There is a need for ... Appropriate testing parameters and availability of reliable laboratories. [Comment 1011, Source Document ph2gov011, Page 17]

Mouvement Vert - Mauricie

Neither the AECL nor the Ontario Hydro document describes the environmental monitoring plan which should be implemented to quantify the real impacts and validate the predictions. [Comment 1474, Source Document pub024, Page 09, Section 2.1.2]

The developer suggests no indicators for monitoring or measuring the project's ecological and social impacts. [Comment 1476, Source Document pub024, Page 09, Section 2.1.2]

National Council of Women of Canada

The whole area and responsibility of long-term inspection, monitoring, maintenance, and repairs of the burial site is not really addressed although it is admitted that this is a centuries-long necessity. [Comment 1319, Source Document phpub035, Page 03]

the monitoring should be done by an independent agency with a clear mandate and powers to enforce its recommendations. Its reports should be public and published at least annually. This issue must be addressed and is, or should be, a most important part of the post closure plans. [Comment 1320, Source Document phpub035, Page 04]

Natural Resources Canada

The guidelines require demonstration of the availability of techniques for assessment of deviations from predicted thermal, geomechanical and hydraulic behaviour ... the EIS ... does not actually demonstrate the appropriateness of the instruments. [Comment 706, Source Document gov005, Page 09, Section 5.13]

Scientific Review Group

no details are provided on which environmental conditions will be monitored and how. [Comment 509, Source Document tec004, Page 106, Section A-2.1.3]

R-Preclosure does not describe, in sufficient detail, nor in a co-ordinated manner, the purpose of preand post-decommissioning monitoring, or how the data gathered will be applied to preclosure activities and assessment, and to ultimate postclosure assessment A framework describing the monitoring activities and their purpose should have been presented. Some important considerations are:

- developing tolerances and control limits for performance measures;

- assisting in the development and refinement of models;

- indicating when and how the public will be informed and involved;
- developing effective record-keeping practices; and

- developing contingency plans for action if tolerances are not met. [Comment 110, Source Document tec004, Page 147, Section D-2.1.14]

OPG RESPONSE

AECL presented a general approach to monitoring in Simmons et al. (1994). AECL also subsequently documented some of the methods that could be used for monitoring the performance of a geologic repository (see Cooper et al. 1997).

The OPG reference concept includes monitoring during and after operations, with a duration of approximately 100 years. This includes an extended monitoring period where the emplacement rooms are backfilled and sealed, but the access tunnels and shafts would remain open.

Whether and when the repository would be fully closed, and the extent and type of post-closure monitoring, would be decided after that period, in consultation with the stakeholders, based on the information available from the 100 years of prior monitoring and on then-available monitoring technologies.

OPG has continued to work on developing monitoring concepts and instrumentation. For example, a report on instruments and systems for monitoring the performance of repository seals was issued in 2001 (Martino et al. 2001).

References:

Cooper, R.B., J.W. Barnard, G.A. Bird, M. Gascoyne, B.M. Ikeda, E.T. Kozak, G.S. Lodha, P.M. Thompson, A.W.L. Wan, D.M. Wuschke. 1997. Monitoring methods for nuclear fuel waste disposal. Atomic Energy of Canada Limited Report AECL-11643; COG-96-611.

Martino, J.B., D.A. Dixon and P.M. Thompson. 2001. Instruments and systems for monitoring the engineering performance of repository seals. Ontario Power Generation, Nuclear Waste Management Division Report 06819-REP-01200-10072-R00.

Simmons, G.R., P. Baumgartner, G.A. Bird, C.C. Davison, L.H. Johnson, J.A. Tamm. 1994. An approach to criteria, design limits and monitoring in nuclear fuel waste disposal. Atomic Energy of Canada Limited Report AECL-10737; COG-94-30.

6.06.02 Engineering - Monitoring - Preclosure

PARTICIPANT COMMENTS

Canadian Geotechnical Society

the CGS believes that a more extended observation period should probably be allowed for in the concept, along with a retrievability option in the event that corrective action must be taken. The exact time span of this observation period would require some analysis, however, it is estimated to be perhaps 100 years or so after closure, to prove by monitoring of the geotechnical and environmental behaviour of the repository that it is operating according to or beyond expectation before the disposal site is sealed to form the final perpetual repository. [Comment 1091, Source Document pub020, Page 11]

This suggestion is a change to the concept by including an initial retrievable storage option coupled with geotechnical monitoring for approximately 100 years or so, to conclusively prove predicted behaviour before finally sealing the repository for perpetuity. [Comment 1085, Source Document pub020, Page iii]

Graham, J.

no precedent exists for a long-term nuclear waste facility. Detailed design should therefore probably include an initial phase of geotechnical monitoring to ensure performance is equal to or better than expectations. [Comment 1415, Source Document ph3pub060, Page 3]

Health Canada

where extended monitoring is required, how long and of what nature is the extended monitoring to take? [Comment 1001, Source Document ph2gov011, Page 12]

Inter-Church Uranium Committee (Fortugno)

What opportunities will the province have to influence pre-closure monitoring [Comment 2103, Source Document ph2pub031, Page 6, Section IV]

OPG RESPONSE

The OPG reference concept includes monitoring during and after operations, with a duration of approximately 100 years. This includes an extended monitoring period (nominally 70 year duration) where the emplacement rooms are backfilled and sealed, but the access tunnels and shafts would remain open.

Whether and when the repository would be fully closed, and the extent and type of post-closure monitoring, would be decided after that period, in consultation with the stakeholders, based on the information available from the 100 years of prior monitoring and on then-available monitoring technologies.

(See also response in Category 6.06.01.)

6.06.03 Engineering - Monitoring - Postclosure

PARTICIPANT COMMENTS

Canadian Geoscience Council

the performance of any initial repository of this magnitude will have to be closely monitored for a very long time in order to verify if the engineering predictions are validated. [Comment 1032, Source Document tec002, Page 10, Section 2.2.1]

Chemical Institute of Canada

the Disposal Concept should ... be sufficiently flexible, or robust, to allow for ongoing monitoring should future generations choose to do so ... It is our feeling that the Concept proposed does have the potential to meet the needs of this broader equity issue even though only the one option - assuring that future generations are not burdened with any responsibility - has been explored in any detail in AECL's Environmental Impact Statement (EIS). [Comment 1107, Source Document tec005, Page i, Section es]

Joint Committee of the Canadian Academy of Engineering and the Royal Society of Canada

An optimal site for a vault can be selected but a body of rock, of the order of cubic kilometers, will contain non-uniformities and fractures whose effects on containment during the next 10,000 years cannot be predicted with certainty. Neither, for that matter, can the effectiveness and durability of the engineered barriers be meaningfully guaranteed for that sort of time span. That is why the disposal concept proposed cannot be considered as a "final solution" in any literal sense of the term. In consequence, options should be left open for long-term monitoring of the site and for possible intervention in case of system failure. [Comment 1156, Source Document ph2tec007, Page 04]

long term monitoring is required to establish as well as possible the success and short comings of the project, and to provide performance and design information for future disposal sites that will most certainly be required if we continue to generate power in this way. [Comment 1174, Source Document ph3pub034, Page 1]

Oblate Conference of Canada

when we find that the AECL proposal gives no specific time frame for monitoring the burial site, we are alarmed. If the Federal-Provincial panel in its report on the McArthur River Uranium Mine Project recommended perpetual monitoring of uranium mine tailings, how much more necessary is perpetual monitoring for spent nuclear fuel? [Comment 1621, Source Document ph3pub213, Page 1]

OECD/NEA Review Group

It is debateable whether any sensible safety case can be made for monitoring post-closure. The repository system is expected to evolve very slowly and there are no performance related parameters which are clearly amenable to measurement and also of obvious safety relevance. However, there may be a social demand for some kind of monitoring which must be met. [Comment 1254, Source Document tec001, Page 18, Section 5.2]

The necessity and the requirements for post closure monitoring need further consideration in all countries and, if considered a desirable course of action, the concepts and technology would need further development. [Comment 1260, Source Document tec001, Page 21, Section 6.2]

Saskatchewan Environmental Society

it is unclear how a non-invasive system could be designed for perpetual monitoring of the area surrounding the containers. This suggests to us that the technology is not yet available to provide the degree of security through very long-term monitoring which would be required for public confidence in a permanent disposal system. [Comment 1694, Source Document ph2tec039, Page 4]

OPG RESPONSE

The OPG reference plan includes monitoring during and after operations, with a duration of approximately 100 years. This plan includes an extended monitoring period (nominally 70 year duration) where the emplacement rooms are backfilled and sealed, but the access tunnels and shafts would remain open to allow access for monitoring and for easier retrieval, if required.

Whether and when the repository would be fully closed, and the extent and type of post-closure monitoring, would be decided after that period, in consultation with the stakeholders, based on the information available from the 100 years of prior monitoring and on then-available monitoring technologies.

(See also response in Category 6.06.01.)

6.06.04 Engineering - Monitoring - Recommendations

6.06.04.01 Engineering - Monitoring - Recommendations - General PARTICIPANT COMMENTS

Health Canada

No provision is given to monitor container integrity after the containers are placed in the vault. While it is understandable that vault integrity should be preserved, no opportunity exists to either monitor or remove defective containers placed in the vault. This must be considered a shortcoming in the proposal. [Comment 998, Source Document ph2gov011, Page 11]

The monitoring of country foods should include those animals and vegetations revealed in the dietary surveys to be important components of the diet, both qualitatively and quantitatively in relation to age groups, sex and special conditions such as pregnancy and the fetus. This monitoring should include heavy metals, including cadmium which concentrates in the kidneys of moose, caribou and deer. Due to long range transport, cadmium is often present even when local sources do not exist. Other inorganics and organics related to the operations should also be included. [Comment 1014, Source Document ph2gov011, Page 18]

Comprehensive monitoring is necessary because of the need for reassurance of the communities and their members. Native cooperation should be utilised in the taking of appropriate samples of country foods including fish, animals and berries. Employment and training, not only in the collection but preparation and storage of the samples, is to be encouraged. It is important that test results be returned to the interested and affected people within a reasonable time frame with an expert interpretation of the information in language that is understandable to the recipient. [Comment 1016, Source Document ph2gov011, Page 19]

Joint Committee of the Canadian Academy of Engineering and the Royal Society of Canada

We also placed emphasis on the need for long-term monitoring to demonstrate the integrity of the facility. The monitoring should not only satisfy present regulatory requirements but could well include the study of indicator species in ways which might detect possible future harmful effects. [Comment 1177, Source Document ph3tec001, Page 3]

Natural Resources Canada

Nothing about detection of microbial activity is mentioned in sections 5.5.3 (Monitoring the Natural Environment) or 7.6.4 (the Biosphere Model). More information is needed on the present state of knowledge of microbes at depth and more analysis (including methods of monitoring) of how these biota may behave within the conceptual system. [Comment 708, Source Document gov005, Page 11, Section 5.4]

Saskatchewan Environmental Society

the most obvious condition which needs to be monitored is the movement of radioisotopes from the containers into the surrounding buffer.... It is not adequate to limit monitoring to the geosphere beyond the vault [Comment 1692, Source Document ph2tec039, Page 3]

Action levels for monitoring should, in fact, be such that the unexpected, rather than the expected system behaviours can be dealt with. It seems logical that the lifetime of the monitoring system should bear some relationship to the lifetimes of the hazardous materials which are being monitored. [Comment 1693, Source Document ph2tec039, Page 4]

Some advances are being made in technologies that might permit the monitoring of used fuel for at least a few years after the closure of the facility.... provide as much information as possible on all emerging technologies that might make it possible for monitoring of used fuel to occur after closure of the facility. [Comment 1673, Source Document pub040, Page 10, Section 16]

Science for Peace (Energy Working Group)

built in ... environmental testing methods ... should be provided which periodically check for physical malfunctioning of the repository, and for environmental impact in regular operation. [Comment 1713, Source Document ph2pub034, Page 4]

OPG RESPONSE

The OPG reference plan includes monitoring during and after operations, with a duration of approximately 100 years.

During the approximately 30-year operational phase, it is envisaged that some containers would be emplaced early in a test area and monitored closely.

After all the containers had been emplaced, the access tunnels and shafts would remain open for an extended monitoring period, nominally 70 years duration. During this period, the open access tunnels would allow continued direct monitoring of the emplacement rooms, and allow for easier retrieval if required.

Whether and when the repository would be fully closed, and the extent and type of post-closure monitoring, would be decided after that period, in consultation with the stakeholders, based on the information available from the 100 years of prior monitoring and on then-available monitoring technologies.

During this entire period, appropriate environmental monitoring would be carried out in the surface environment. Appropriate baseline data would also be collected and presented in the Environmental Assessment, together with site environmental studies. A description of planned monitoring programs, tailored to the particular site, would be part of submissions for both EA approval and a CNSC Construction Licence..

(See also response in Category 6.06.01.)

6.06.04.02 Engineering - Monitoring - Recommendations - Health

PARTICIPANT COMMENTS

Canadian Coalition for Ecology, Ethics and Religion

Monitor early warning indicators of biochemical stress, such as chromosomal aberrations, in addition to cancers, birth defects etc. [Comment 1850, Source Document ph2pub011, Page 1]

Centre for Environmental Health

The role of biomonitors is to provide dosimetric information when an accidental exposure is possible or suspected.... In such cases, the appropriate assays can provide evidence of exposures and an estimate of their magnitude.... When exposure is suspected, the action required depends upon the suspected type of exposure, and when the exposure is thought to have occurred. A choice can then be made from the assays that are compared in Table 8. We suggest that in cases of serious levels of exposure, that more than one assay be used. This provides an internal check against spurious results. We also recommend that ample blood samples be collected (50-150 ml) and the mononuclear fraction be prepared, properly frozen and stored in liquid nitrogen in case more testing in required. [Comment 1425, Source Document phpub003, Page 38]

Health Canada

The focus of any health monitoring program (i.e., physical and/or psychological health) is not discussed. We note the absence of any discussion differentiating between monitoring physical and psychological health. [Comment 944, Source Document gov006, Page 12]

biophysical monitoring of contaminants through the food chain and dietary surveys during the life of the project must be carried out if risk assessments are to be conducted and risk management decisions are to be made. [Comment 983, Source Document ph2gov011, Page 01]

United Church of Canada

It is desirable to have a way of detecting susceptibility to or occurrence of human health impact due to exposure to ionizing radiation that would be an early indicator of potential health risk.... Evaluation of chromosome aberrations may prove useful as an early indicator of biochemical stress and susceptibility to serious health impact from exposure to ionizing radiation. Investigations which could lead to the re-defining of risk in terms of chromosome aberrations rather than fatal cancers and serious genetic diseases should be supported. [Comment 1741, Source Document phpub124, Page 3-17, Section 3]

OPG RESPONSE

AECL's 1994 EIS documents the baseline monitoring for a geologic repository facility. Monitoring would include human exposure pathways, and the natural environment.

While subsequent monitoring of the health of humans or natural biota may be part of the long-term monitoring plans, no significant release of radionuclides from the repository is expected, and therefore simple monitoring for the presence of used fuel radionuclides in the environment and ecosystem components would provide sufficient indication of any potential problems long before any biological impact.

6.07 Engineering - Mitigation

6.07.01 Engineering - Mitigation - General

PARTICIPANT COMMENTS

Canadian Coalition for Nuclear Responsibility (Regroupement pour la surveillance du nucléaire)

discuss the ... practical implications of our society possibly making a mistake by approving a disposal concept now, only to find, after closure, that the predictions were wrong and that significant amounts of radioactive contaminants are escaping from the repository into the biosphere. [Comment 1882, Source Document pub049, Page 15]

Health Canada

What contingencies, if any, for mitigation exist? [Comment 1002, Source Document ph2gov011, Page 13]

Natural Resources Canada

The guidelines require ... demonstration of contingency plans.... the EIS ... does not describe contingency plans [Comment 906, Source Document gov005, Page 09, Section 5.13]

Scientific Review Group

Limited identification of practical measures that could be used to prevent, minimize or mitigate and manage environmental effects and safety hazards also exists. [Comment 477, Source Document tec004, Page 096, Section 7.8]

More information on the effectiveness of mitigative measures to bring impacts to an acceptable level is required... These measures should be described in sufficient detail to allow an evaluation of their efficacy and availability in the case of a disposal facility somewhere in the Canadian Shield. This has usually not been done. [Comment 121, Source Document tec004, Page 149, Section D-2.2.5]

OPG RESPONSE

OPG has planned for monitoring both during and following closure of a repository. Monitoring could extend for 100 years or more. During the extended monitoring period, the emplacement rooms are backfill and sealed, but the access tunnels and shafts would remain open. This would make retrieval easier, if required. Stepwise development of the repository taking account of site conditions and information collected during earlier stages of construction would also reduce the probability of the need for mitigation.

OPG considers retrieval to be the ultimate contingency response. For the 1994 EIS, AECL discussed retrieval of emplaced wastes during the preclosure and postclosure phases (see Simmons and Baumgartner 1994, Acres 1996). No significant technical issues were identified, although there would have to be engineering design and demonstration for the equipment. Currently, SKB (Sweden) are conducting full-scale container retrieval tests at their underground research laboratory at Aspo (SKB 2000). Since the OPG reference container is similar to the Swedish concept, we expect much of this technology demonstration would apply. We further expect that similar tests would be completed at the Canadian repository possibly as part of the closure of a highly-instrumented test container area.

Normal contingency plans would be in place during the construction, operation, decommissioning and closure of a repository. Specific details would be presented as part of the Environmental Assessment and the subsequent applications for the relevant CNSC licenses (e.g. construction, operation).

References:

Simmons, G. and P. Baumgartner. 1994. The disposal of Canada's nuclear fuel waste: engineering

for a disposal facility. Atomic Energy of Canada Limited Report, AECL-10715, COG-93-5.

Acres International Limited, SENES Consultants Ltd., SPAR Aerospace Ltd. And Davy International. 1996. Feasibility of

retrieval of nuclear fuel waste from a sealed disposal vault. AECL TR-M-44.

SKB. 2000. Aspo hard rock laboratory annual report 1999. SKB Report TR-00-10. Stockholm, Sweden.

6.07.02 Engineering - Mitigation - Retrieval

PARTICIPANT COMMENTS

Campaign for Nuclear Phaseout

include a thorough examination of post-closure emergencies. This would involve the identification of worst case scenarios.... outline scenarios and proposed methodologies for the removal of radioactive contaminants that have breached the containment system, including absorbed contaminants in the aquifer system.... describe how work would be undertaken in a contaminated shaft, including levels of radiation that workers and the public would be exposed to.... describe the circumstances (degree of leakage) that would result in an effort to retrieve waste and how retrieval would take place in a situation where the repository had become contaminated by the leakage. this would include information on levels of radiation that workers and the public would be exposed to. [Comment 1784, Source Document pub027, Page 21, Section III.C]

Canadian Coalition for Nuclear Responsibility (Regroupement pour la surveillance du nucléaire)

the only event which would plausibly precipitate a retrieval operation would be a massive failure of the repository. Under those circumstances, the underground contamination would be so severe as to preclude any effective retrieval operation. [Comment 1911, Source Document cs031, Page 04]

Canadian Geoscience Council

We recommend that retrievability, repositioning, and even movement of the waste also be considered as options if serious geologic discoveries or engineering problems indicate such a need. [Comment 1033, Source Document tec002, Page 12, Section 2.3.1.2]

Chemical Institute of Canada

the Disposal Concept should ... be sufficiently flexible, or robust, to allow for ... active intervention in the case of future advances in technology and economics. It is our feeling that the Concept proposed does have the potential to meet the needs of this broader equity issue even though only the one option - assuring that future generations are not burdened with any responsibility - has been explored in any detail in AECL's Environmental Impact Statement (EIS). [Comment 2142, Source Document tec005, Page i, Section ES]

Concerned Citizens of Manitoba

No reference is made to the methods which could be safely used to excavate shafts, drive tunnels, and otherwise gain access to sealed rooms 500-1000 metres below the surface of the earth without disturbing or destroying the containment mechanisms or, in the case of an emergency retrieval, allowing for the further spread of radiation as a result of further disturbing the geo-sphere. Even in the pre-closure phase, access to sealed emplacement boreholes would require removal of bulkheads by using "drill-and-blast excavation" or "hydraulic rock breakers" (R-Facility p 286), either of which is likely to further disturb surrounding rock and allow for the additional spread of radiation if the reason for the retrieval is broken containment system. [Comment 1949, Source Document pub034, Page 4]

We can find no reference to "how retrieval can be facilitated in the design of the concept." as mandated in the guideline. It is also unclear how it would be determined that an emergency retrieval was necessary in the post-closure phase, or what level of contamination of the bio- or geo-sphere would result in such retrieval, since AECL is not proposing any on-going monitoring of the vaults after closure. [Comment 1951, Source Document pub034, Page 4]

Environment Canada

It is critical to state a link between decision-making with respect to monitoring and remedial actions (e.g. the removal of waste from the vault which might be undertaken in response to results of on-going monitoring during the operational and post-operational phases of concept implementation). [Comment 891, Source Document gov003, Page 33, Section 2.15]

Graham, J.

Design should also include a retrievability option to permit remediation if performance expectations are not met. [Comment 1417, Source Document ph3pub060, Page 3]

Health Canada

seismic activity may play a role in premature destruction of containers. In such an event, is there any plan to recover intact and damaged containers for transfer to an alternate site? [Comment 1003, Source Document ph2gov011, Page 13]

Joint Committee of the Canadian Academy of Engineering and the Royal Society of Canada

we recommend that the provisions for decommissioning and closing the facility be reconsidered with a view to designing the facility in such a way that access in the post closure period will be possible with little difficulty. [Comment 1168, Source Document ph2tec010, Page 08, Section E.3]

Although a number of serious though highly improbable problems are considered in the EIS, it does not clearly outline what the response would be should the stability of the repository by compromised. It may not be possible to define the response to some emergencies, but a description of some disruptive scenarios, such as enhanced fracturing of wall rocks due to thermal or seismic effects, and what would be done to alleviate the resulting problems would be useful to consider. For example, are there conditions under which an already filled part of a vault would be emptied? [Comment 1194, Source Document phpub031, Page 6]

Mouvement Vert - Mauricie

In the context of a serious problem involving radioactive contamination of the vaults, how could the irradiated fuel be removed and the site decontaminated? [Comment 1481, Source Document pub024, Page 17, Section 2.2.3]

Assuming the concept functions normally, how, and until when, would it be possible to remove the plutonium from the vaults for reprocessing or for any other civil or military application? [Comment 1482, Source Document pub024, Page 17, Section 2.2.3]

National Action Committee on the Status of Women

The EIS also does not provide a plan for the retrieval of the waste from a sealed and decomissioned vault in the case of an emergency [Comment 1282, Source Document pub026, Page 24, Section 7.2]

What health and safety conditions would exist if retrieval was to become necessary under both normal and accident conditions? ... What types of protection would be offered to workers under these conditions, given that there are no current exposure limits for ARW's under accident conditions? [Comment 1300, Source Document pub026, Page 34, Section 7.3.3]

Natural Resources Canada

Waste retrieval after closure is briefly mentioned in sections 3.6.6 and 5.8.9 but the EIS does not meet the requirement of the guidelines to outline plans for retrieval after closure for emergency reasons, it does not indicate the potential cost, and although it mentions some of the technical and safety considerations, it does not indicate the cost of retrieval or examine to what extent provisions for retrieval would affect the safety of the concept. [Comment 704, Source Document gov005, Page 06, Section 3.3]

Northwatch

the EIS should describe retrieval made necessary due to unforeseen circumstances, eg. ruptures, leaks etc, and should describe the circumstance (degree of leakage) that would result in a decision to retrieve the waste, and how retrieval would take place in a situation where the repository had become contaminated by the leakage [Comment 1359, Source Document pub046, Page 10, Section d]

Northwatch (Lloyd)

the EIS should describe retrieval made necessary due to unforeseen circumstances, eg. ruptures, leaks etc, and should describe the circumstance (degree of leakage) that would result in a decision to retrieve the waste, [Comment 1530, Source Document ph2tec045, Page 12]

Deficiencies Which Emerged or Remain Outstanding After Discussion in the Phase II Tehncial Hearing Sessions ...

-decision triggers to retrieve waste due to unexpected developments during operation [Comment 1533, Source Document ph2tec045, Page 22]

OECD/NEA Review Group

Retrievability is feasible in principle in plutonic rocks but may have to be further elaborated for specific repository concepts. [Comment 1261, Source Document tec001, Page 21, Section 6.2]

Provincial Council of Women of Ontario

there was no thought to retrievability and the ability of our children's grandchildren being able to intervene. [Comment 1657, Source Document ph3pub130, Page 6]

Science for Peace (Energy Working Group)

We would like to see an elaboration of the degree of accessibility and the cost of a repair operation should it become necessary. [Comment 1714, Source Document ph2pub034, Page 4]

OPG RESPONSE

In the 1994 EIS, AECL discussed retrieval of emplaced wastes during the preclosure and postclosure phases (see Simmons and Baumgartner 1994, Acres 1996). No significant technical issues were identified, although there would have to be engineering design and demonstration for the equipment.

These assessments were conceptual in nature, however, and more analysis could be carried out. This analysis could also consider the implications of contaminated groundwater around the repository on the retrieval, such as increased reliance on remote-operated mining machinery.

Note that currently, SKB (Sweden) are conducting full-scale container retrieval tests at their underground research laboratory at Aspo (SKB 2000). Since the OPG reference container is similar to the Swedish concept, we expect much of this technology demonstration would apply. We further expect that similar tests would be completed at the Canadian repository.

References

Acres International Limited, SENES Consultants Ltd., SPAR Aerospace Ltd. and Davy International. 1996. Feasibility of retrieval of nuclear fuel waste from a sealed disposal vault. AECL report TR-M-44.

Simmons, G. and P. Baumgartner. 1994. The disposal of Canada's nuclear fuel waste: engineering for a disposal

facility. Atomic Energy of Canada Limited Report AECL-10715, COG-93-5.

SKB. 2000. Aspo hard rock laboratory annual report 1999. SKB Report TR-00-10. Stockholm, Sweden.

6.07.03 Engineering - Mitigation - Decommissioning

PARTICIPANT COMMENTS

Health Canada

the measures to be taken to restore the environment during decommissioning are not described in detail. [Comment 941, Source Document gov006, Page 12]

OPG RESPONSE

AECL's 1994 EIS discussed decommissioning at a conceptual level of detail. More detailed decommissioning plans would be developed and documented at the appropriate stages of the deep geologic repository program.

6.07.04 Engineering - Mitigation - Microbes

PARTICIPANT COMMENTS

Scientific Review Group

there is the potential to manage strategically the microbial population at specific sites to extend the containment of the radionuclides (e.g. within redox front focused bioaccumulates). [Comment 311, Source Document tec004, Page 244, Section I-2.5]

OPG RESPONSE

There has been a broad international effort on microbial behavior in a repository since the 1994 AECL EIS. In the Canadian program, the multi-year in-situ Buffer-Container Experiment and the Isothermal Test (Stroes-Gascoyne et al. 2000) have examined microbial effects as an important part of their objectives. Recent summaries of the state-of-knowledge of microbial activities around the repository are given in Pedersen (2000) and Stroes-Gascoyne et al. (1997).

The main objective of this effort is to design the emplacement room seals so as to minimize microbial activity in the vicinity of the containers in order to extend the container lifetime. Any active use of microbes to contain radionuclides would be a secondary goal compared to container integrity, and would be complex to assure, given the changing thermal/moisture/chemical system.

References:

Pedersen, K. 2000. Microbial processes in radioactive waste disposal. SKB report TR-00-04. Stockholm, Sweden.

Stroes-Gascoyne, S., C.J. Hamon and P. Vilks. 2000. Microbial analysis of the Isothermal Test at AECL's Underground Research Laboratory. Ontario Power Generation 06819-REP-01200-10023-R00.

Stroes-Gascoyne, S. 1997. Microbial aspects of the Canadian used fuel disposal concept - status of current knowledge from applied experiments. Ontario Hydro report 06819-REP-001200-0026-R00.

6.07.05 Engineering - Mitigation - Preclosure Effluents

PARTICIPANT COMMENTS

Scientific Review Group

The document states " ... trace metal content (e.g. U) may also increase in pond water during the operational period ... treatment facilities can be set up to deal with these types of occurrences" (R-Preclosure 1994: p.6-97). This statement begs the following questions: how much will metal contents increase? Which metals? What type of treatment facilities? [Comment 122, Source Document tec004, Page 150, Section D-2.2.5]

OPG RESPONSE

All waste water from the operation of a deep geologic repository would be tested and treated, if required, prior to discharge to the environment, as required by federal and provincial standards. AECL' s Underground Research Laboratory (URL) in

Canadian Shield granite in Manitoba provides a specific example of the possible nature of trace metals and treatment systems. The discharge waters and their treatment are described in the URL annual reports (e.g. Ross et al. 2000, Underground Research Laboratory environmental monitoring program and results for 1999, AECL Report RC-261-12, URL-GEN-R026).

6.07.06 Engineering - Mitigation - Resilience of Ecosystems PARTICIPANT COMMENTS

Scientific Review Group

The robustness of environmentally sensitive ecosystems may be overstated.... sweeping statements promising that impacts will be minimized because of the natural resilience of ecosystems, combined with appropriate mitigative measures. What are the case studies to corroborate such generalizations? ... what effects from non-radiological stressors are expected? How would these be minimized and mitigated? [Comment 124, Source Document tec004, Page 150, Section D-2.2.5]

OPG RESPONSE

While the robustness of ecosystems should not be overstated, most natural systems have a significant degree of resilience as illustrated, for example, in their tolerance to the cycle of seasons, in their recovery from forest fires, and even in their recovery around the Chernobyl site.

It is therefore reasonably expected that, over time, natural and assisted regeneration after decommissioning would repair damage due to non-radiological stressors. However, impacts on the ecosystem, together with mitigative measures, certainly for any environmentally-sensitive ecosystems in the vicinity of a repository - would have to be considered as part of a site-specific Environmental Assessment.

6.07.07 Engineering - Mitigation - Groundwater

PARTICIPANT COMMENTS

Scientific Review Group

Assessment of the influence of the underground vault on groundwater flow regimes ... is incomplete.... How changes in flow characteristics would be mitigated is left unstated. [Comment 123, Source Document tec004, Page 150, Section D-2.2.5]

OPG RESPONSE

In AECL's 1994 EIS, the impact of underground openings on groundwater flow in the vicinity of a deep geologic repository was illustrated for the Whiteshell Research Area (see PRD-Geosphere). This evaluation included drawdown around the vault and effects on surface discharge areas. These changes would recover naturally after the repository is closed. Whether the changes require mitigation in the interim would require site-specific evaluations that would normally be part of the site-specific Environmental Assessment.

6.07.08 Engineering - Mitigation - Chemical Toxicity

PARTICIPANT COMMENTS

Scientific Review Group

AECL has stated that "... environmental protection is accomplished by regulating the concentration of chemically toxic contaminants in surface water and soil ..." (R-Biosphere 1993: p.11), but has given no indication of how such regulation will be accomplished with regard to the bromine, chromium, selenium, and other toxic materials that may be released from the fuel waste, fuel sheaths, and containers [Comment 414, Source Document tec004, Page 067, Section 6.4.2]

It is stated (R-Biosphere 1993: p.364) that Canadian Water Quality Guidelines will be used to establish criteria for chemical contamination, and that BIOTRAC predictions of radionuclide concentrations in surface water, soil, and air can be compared with chemical criteria to demonstrate acceptability; but there is no mention of how the nuclear fuel waste disposal system would or could be modified in the event that the chemical toxicity was found to be unacceptable. [Comment 415, Source Document tec004, Page 068, Section 6.4.2]

OPG RESPONSE

During operation, waste water from the repository and surface facilities would be tested and treated, if required, prior to discharge to the environment, as required by federal and provincial standards. For example, AECL's Underground Research Laboratory routinely monitors and treats the water from underground operations (see Ross et al. 2000, Underground research laboratory environmental monitoring program and results for 1999, AECL Report RC-261-12, URL-GEN-R026)

For the long-term, chemical toxicity is minimized by use of appropriate materials for the engineered barrier systems. In the OPG reference concept, the primary engineering materials are steel, copper, clays and concrete.

Finally, the effects of any toxic elements present (notably in the used fuel) are minimized by the multiple barriers inherent within the design and location of the deep geologic repository itself.

6.07.09 Engineering - Mitigation - Premature Closure

PARTICIPANT COMMENTS

Campaign for Nuclear Phaseout

the EIS [does not] consider scenarios for premature closure of the facility due to exposure levels becoming so high that people will no longer be able to work in the facility. [Comment 1822, Source Document pub027, Page 35, Section III.H]

Concerned Citizens of Renfrew County and Area

The EIS does not consider whether increasing radiation levels could force premature closure or prolonged shut-down of the facility. [Comment 1980, Source Document ph3pub216, Page 04]

OPG RESPONSE

OPG does not believe that the deep geologic repository facility would be closed prematurel due to high radiation levels.

First, it should be clear that the emplaced containers are well-shielded and do not pose a hazard.

Second, the repository will be designed from the perspective of safety during the operational phase and will include redundancy; systems, processes and operations relevant to safety will be designed so that a single failure will not compromise environmental, public or worker safety. If there was a spill, it would be cleaned up.

Finally, if there were an unexpected release from containers, it would be detected long before it became a personnel hazard, and appropriate countermeasures could be taken, up to and including retrieval of the affected containers.

6.08 Engineering - Resource Availability

PARTICIPANT COMMENTS

Chemical Institute of Canada

The CIC agrees that both titanium and copper meet the exacting performance requirements for this application. Though both are acceptable, the CIC believes that because of its intrinsic properties copper is the better choice for this application not titanium as proposed by AECL. However, since both are technically acceptable, the CIC further suggests that broader environmental stewardship and socioeconomic factors should be considered in making the final selection. [Comment 1125, Source Document tec005, Page 21&22, Section III.3]

Environment North

Sixty thousand containers made of pure copper, 25 mm thick - - if each container weighs, say, 200 kg., that will use up 12,000 tons of copper that future generations will surely need. [Comment 2086, Source Document ph3pub106, Page 1]

Saskatchewan Environmental Society

where is all this copper going to come from and at what price? [Comment 1700, Source Document ph2tec039, Page 7]

Scientific Review Group

The possibility of future intrusion into the vault to recover this resource [metal in the waste disposal containers] should be a cause for concern. This consideration should be a factor in the final selection of the material for the containers. [Comment 2144, Source Document tec004, Page 045, Section 6.2.1]

It is inappropriate simply to compare the cost of copper and titanium per kilogram of contained uranium, in 1995 dollars, since there are other factors which would influence the final cost. These include: material availability, the cost of fabrication and handling of the container, the form of the engineered barriers to be installed, the method of emplacement, and, potentially, the need for a thicker-walled titanium container. [Comment 43, Source Document tec004, Page 123, Section B-2.2.1]

Nickel ... is in plentiful supply in Canada. [Comment 485, Source Document tec004, Page 125, Section B-2.2.2]

It is not clear in R-Preclosure that due consideration has been given to the long-term security of supply of some resources such as titanium and usable bentonite.... The consequences of unavailability of the supply of suitable buffer material during the operational phases should have been investigated. [Comment 102, Source Document tec004, Page 146, Section D-2.1.4]

R-Preclosure does not provide sufficient detail on ... the amounts of resources required such as fuel, explosives; [Comment 112, Source Document tec004, Page 148, Section D-2.1.16]

OPG RESPONSE

In 1999, OPG reviewed the selection of a corrosion barrier material for used fuel containers in a deep geologic repository (Maak 1999). The study examined a number a candidate corrosion-barrier materials (e.g., titanium, copper, steel, nickel) and commissioned an international peer review of the report findings. The study recommended the use of a copper.

In the reference Canadian design (e.g., Russell and Simmons 2003), the main engineering materials required are copper, steel, clay and cement. Although significant amounts are used, these are all plentiful materials. Nonetheless, OPG is continuing to assess options that minimize the use of such

materials. For example, the amount (cost) of copper is a factor in the selection of the present reference container size. Also, OPG (following the lead of Sweden and Finland) is evaluating a horizontal borehole emplacement concept, which would use much less clay than in-room emplacement.

References:

Maak, P. 1999. Selection of a corrosion-barrier primary material for used-fuel disposal containers. Ontario Power Generation Report 06819-REP-01200-10020-R00.

Russell, S.B. and G.R. Simmons. 2003. Engineered barrier systems for a deep geologic repository in Canada. Proc. 10th International High-Level Radioactive Waste Management Conference, Las Vegas, USA.

6.09 Engineering - Case Studies

PARTICIPANT COMMENTS

Canadian Coalition for Nuclear Responsibility (Regroupement pour la surveillance du nucléaire)

Le concept de stockage, lui, vise à mettre des choses sous terre plutôt que d'en extraire. Dans ce domaine, nous n'avons que très peu d'experience.

[The disposal concept aims to place things into the ground rather than to extract them. In this area we have very little experience.] [Comment 1903, Source Document ph3pub192, Page 1]

Canadian Geotechnical Society

Canadian geotechnical, geoscience and mining expertise have a proven track record in constructing stable underground facilities in much more difficult geological conditions than will likely be encountered in the final repository. [Comment 1083, Source Document pub020, Page ii]

Ecosystem Approach Group

The disposal concept could not be implemented with available technology. [Comment 2043, Source Document pub033, Page 12]

Energy Probe (Rubin)

if we are really trying to gain confidence that we have succeeded in achieving a prudent solution, we must fill key research gaps ... We must study, and understand, failed containment wherever it has occurred, so that we may avoid duplicating its conditions.... We must study, and understand, failed engineered systems, most of which were "proved safe" before they failed.... We must study, and understand, the institutional failures that helped to create the failed engineered systems. [Comment 2082, Source Document ph2tec024, Page 5]

National Council of Women of Canada

The connection of operating problems to the Nuclear Waste Proposal is that unforeseen weaknesses along with poor supervision of workers validates concerns about what will or could really happen if the burial vault is prepared and the waste interred. [Comment 1497, Source Document ph3pub185, Page 4]

Natural Resources Canada

The EIS does not meet the specific requirements of the guidelines to discuss the use of data from existing deep large excavations and natural caves, and the time period over which such information applies, nor does it discuss additional research that might be needed or be useful for model validation. The approach of the EIS is to take a stance conservative enough to obviate the need for additional research. [Comment 709, Source Document gov005, Page 15, Section 6.3]

Robertson, J.A.L.

there should be no question that the concept is physically feasible. Essentially, it calls on two technologies in which Canada is preeminent: hard-rock mining and the remote-handling of radioactive materials. [Comment 1458, Source Document phpub004, Page 28]

Scientific Review Group

The experience of the mining community in terms of case studies of large, deep underground excavations, has not been included in this document. [Comment 513, Source Document tec004, Page 127, Section B-2.2.4]

OPG RESPONSE

In preparing the in-floor borehole case study presented with the EIS, AECL used the expertise of Canadian mining and geotechnical engineering consultants (Redpath et al. 1992). AECL also had Acres International document some large construction projects that had been successfully completed in the Canadian Shield environment (Acres 1993). In any future design studies, OPG would continue to ensure that the appropriate mining and geotechnical engineering expertise was included on the study team.

OPG agrees that it is reasonable to be aware of the experiences from similar underground facilities. As one activity in this area, OPG is a participant in the European CROP project, in which the practical lessons learned in the various national underground laboratories are being assembled. Reviewing and assessing the experience within the Canadian mining community may also be useful.

References

Acres International Limited. 1993. Case histories of underground civil engineering projects in the Canadian Shield. Atomic Energy of Canada Limited report TR-M- 18

J.S. Redpath Mining Consultants Limited, Golder Associates and the Ralph M. Parsons Co. 1992. Used-fuel disposal centre - A reference concept. Atomic Energy of Canada Limited report TR-M-3.

6.10 Engineering - Research

PARTICIPANT COMMENTS

Bruce Peninsula Environment Group

We strongly encourage AECL to abandon its attempt to gain approval for the concept of underground disposal of nuclear fuel waste, improve its storage facilities for the next few hundred years, learn what actually happens to small samples of retrievable waste in underground burial conditions over a long period of time. Then in three hundred years time, and only then, could AECL reconsider the concept of fuel waste burial and make a decision on disposal methods. [Comment 1775, Source Document ph3pub151, Page 1]

Canadian Geotechnical Society

One extremely important aspect of the disposal concept is the ability to adequately seal all exploratory boreholes and access shafts once the repository is filled. It is felt that this aspect of sealing of openings would benefit from a large scale field trial such as at the URL or at a candidate site. Of concern is the potential for "hydraulic compression" or "hydraulic fracturing" to occur between the seals and the rock interface in both boreholes and access shafts, thus reducing the integrity of such seals. [Comment 1102, Source Document pub020, Page 13]

there is a need to adequately seal both natural and induced rock fractures in the excavation-disturbed zone (EDZ) around all other access tunnels, caverns and associated openings within the repository. Although there is a great deal of detail given in the EIS documents regarding such sealing and grouting materials, i.e., bentonites and cement-based grouts supported by extensive laboratory research, an in situ field demonstration within a typical setting such as the URL could be beneficial. [Comment 1103, Source Document pub020, Page 13]

provision of an adequate sealing and grouting program is one of the key defenses against radionuclide migration to the surface environment, therefore, this very important issue requires further discussion and would benefit from a field demonstration at either the Underground Research Laboratory or at a candidate site under actual rock conditions. [Comment 1086, Source Document pub020, Page iv]

Chemical Institute of Canada

I suggest that the titanium option be eliminated as soon as possible and that AECL concentrate its efforts on answering what questions remain concerning the use of copper. Some that come to mind include: (1)mechanical effects of low temperature creep, (2)use of chemical backfills to remedy oxidation potential in the vicinity of the copper surface; for example, a backfill containing an iron oxide should maintain reducing conditions even in the presence of oxygenated groundwater, (3) possible additions of secondary metallic barriers to prevent egress in the event of a mechanical puncture. [Comment 1134, Source Document ph2tec026, Page 2]

Durham Wetlands and Watersheds

No discussion in the EIS of testing of materials in Earth Orbit aboard a Long Duxation Exposure Vehicle (LDEV). [Comment 2007, Source Document pub043, Page 5]

Environment Canada

Given the uncertainty regarding when a gas phase will appear, and its effect on the transport of volatile radionuclides, further work should be performed to determine whether gas generation and gas migration (or gas-induced migration) of radionuclides is significant with respect to postclosure assessment. If significant, gas source terms may need to be calculated for 2-phase flow modelling of radionuclide transport to the biosphere. [Comment 868, Source Document gov003, Page 25, Section 2.12]

Joint Committee of the Canadian Academy of Engineering and the Royal Society of Canada

there would be merit in further work on the following: (i)confirmation that the self-sealing properties of the grouts would be effective over long periods of time and under the anticipated operational conditions. (ii)providing means for monitoring the development of new fractures, or opening up of existing ones, and the effectiveness of self-sealing, at least during the pre-closure phase and subsequent monitoring period prior to closure. (iii)development of grouting equipment specifically for this Concept, with installations capable of multiple injections into fractures during the pre-closure stage, and perhaps also in critical areas, remotely, during the monitoring period prior to closure.... Whereas grouting of fine fissures or joints has precedent in sealing concrete water retaining structures and bedrock for example, the available experience is not representative of the scale and desired results in this case, particularly the self-sealing performance of the grouts. These developments are not expected to occur as part of normal improvements in grouting technologies. [Comment 1163, Source Document ph2tec007, Page 09]

Montreal Raging Grannies

Run 10,000 year trials - without toxic contents -Then we'll say ok! we think that makes sense! [Comment 1472, Source Document ph3pub186, Page 1]

Northumberland Environmental Protection

In many fields involved in this concept, the science is not as well defined or is still developing, such as corrosion science, PITTING of metals, Microbial-Influenced Corrosion, mechanisms of microfilms and biofilms, biosphere flow/transport modelling-to name a few. The short term experiments that could be done, remain incomplete. [Comment 1503, Source Document cs028, Page 1]

Northwatch and Campaign for Nuclear Phaseout (Kreusch, Neumann, and Gruppe Ekologie)

Only long-term experiments under real repository conditions can give a good answer whether corrosion is neglible. [Comment 1584, Source Document ph2tec044, Page 09, Section 3]

Northwatch and Saskatchewan Environmental Society (Richardson)

Both the URL at Whiteshell and the HRL at Aspo were developed to examine the in-floor concept, and this has occupied much of the time to date. It is important that the in-room concept is subjected to a similar level of investigation [Comment 1595, Source Document ph2tec037, Page 13, Section 4.2]

SKI still consider the state of knowledge regarding construction at depth as incomplete, in terms of rock supportability and prediction of ground conditions. The work done at the URL by AECL is important in this regard, and it is crucial that further work is done relating the high-stress conditions found in the deeper parts to the performance of the disposal concept variant as now proposed. [Comment 1597, Source Document ph2tec037, Page 14, Section 4.2]

SKB plan to develop a prototype repository at Aspo, to develop and demonstrate the necessary emplacement technologies. AECL should be instructed to do the same at Whiteshell for both the infloor and in-room concepts, before final decisions are taken on which to apply. [Comment 1601, Source Document ph2tec037, Page 16, Section 4.3]

OECD/NEA Review Group

given the current successful status of short-term corrosion data gathering and given the envisaged, fairly long time frames for the siting and construction of the actual repository, the Group advises the Canadian Program to start a parallel programme of long-term studies representative of in-situ conditions. [Comment 1203, Source Document tec001, Page 07, Section 3.1.2]

it is being proposed to construct elliptical galleries for in-room emplacement which would avoid stress concentration on galleries surfaces and eliminate the potential for spalling. In-room emplacement would also make the performance of the repository less dependent on the location of a flowing zone, whether above or below the repository horizon. The Group felt that these studies could usefully be built into any future R&D programme at the URL. [Comment 1208, Source Document tec001, Page 09, Section 3.1.4]

The elliptical vault, in-room container emplacement alternative is interesting and raises a number of new questions which will need to be evaluated in real scale tests: ...

- the rehydration behaviour could be complex in the immediate vicinity of the containers ...

- the stress and excavation damage zone (EDZ) implications of the design need testing

- the emplacement and settling behaviour of the different buffer blocks and loose fill will need testing

- the potential interactions of the concrete pad and the bentonite need to be addressed. [Comment

1251, Source Document tec001, Page 17, Section 5.2]

The disposal concept is based on reasonably achievable materials and technology. However, the demonstration and testing of some key technological features will have to continue or be initiated. [Comment 1258, Source Document tec001, Page 21, Section 6.2]

Further large-scale demonstration may need to take place at a later date and would necessarily be site specific at that stage. [Comment 1259, Source Document tec001, Page 21, Section 6.2]

Scientific Review Group

Additional data on buffer and backfill densities as related to hydraulic conductivity are needed ... In order to characterize clay material properties more completely, and to justify selection of the source for the clay material, additional laboratory testing of clay density as related to hydraulic conductivity response clay-sand and clay-crushed granite mixtures should have been performed. [Comment 38, Source Document tec004, Page 122, Section B-2.1.11]

design of the containers is not adequately supported by a test program. Very few tests have been performed on the reference thin-walled titanium container. [Comment 48, Source Document tec004, Page 124, Section B-2.2.1]

There are a number of factors (features, events, processes) that are identified as requiring further research (e.g. biological activity in the vault, gases in the vault). Given the potential importance of these factors in determining outcome, the SRG questions whether the risk characterization truly encompasses all plausible dose outcomes (including those with very low probability). [Comment 198, Source Document tec004, Page 190, Section E-4]

OPG RESPONSE

The Canadian Nuclear Waste Management Organisation is reviewing approaches for long-term management of used fuel, including long-term storage

OPG has conducted work to further the evolution of the AECL concept of a deep geologic repository. The reference container design is based on a copper corrosion-barrier outer vessel and a carbon steel inner vessel as the load-bearing component (Russell and Simmons 2003) This updated container design is consistent with similar repository concepts in Sweden and Finland. OPG is preparing preliminary design requirements for repository sealing systems. Using these requirements as the basis, OPG has initiated a program in repository seal engineering to define the issues and then develop the material properties and design tools/methods necessary to design repository effective seals that would satisfy the preliminary design requirements (Read and Chandler 2002). As part of the siting of a geological repository, the sealing systems would be demonstrated and detailed safety and performance assessments of repository seals would be conducted. Designs would be tailored for site conditions.

More generally, the Canadian research program is summarized each year in Annual Reports (e.g., Gierszewski et al 2003).

References:

Gierszewski, P., S. Russell, A. D'Andrea, F. Garisto, M. Jensen, T. Kempe, P. Maak, G. Simmons and A. Vorauer. 2003. Deep Geologic Repository Technology Program - Annual Report 2002. Ontario Power Generation Report, 06819-REP-01200-10100-R00.

Read, R.S. and N.A. Chandler. 2002. Development and integration of tools for engineering design of repository sealing systems (ENDRES) project status - March 2002. Ontario Power Generation, Nuclear Waste Management Division Report 06819-REP-01300-10051-R00. Toronto, Canada.

Russell, S.B. and G.R. Simmons. 2003. Engineered barrier systems for a deep geologic repository in Canada. Proc. 10th International High-Level Radioactive Waste Management Conference, Las Vegas, USA.

6.11 Engineering - Security and Safeguards

PARTICIPANT COMMENTS

Campaign for Nuclear Phaseout

The current EIS fails to provide a detailed examination of issues associated with plutonium theft and other criminal acts. What measures are proposed to address this risk, with regard to ... on-site storage and handling? [Comment 1789, Source Document pub027, Page 23, Section III.C]

Durham Wetlands and Watersheds

measures to protect against terrorist attack, organized crime hijacking of waste, ground level nuclear strikes and armed invasion [should] be included in the EIS.... measures to ensure the internal security of the Facility [should] be included as part of the EIS. [Comment 2001, Source Document pub043, Page 4]

Ligue des femmes du Québec

Car or truck terror bombs were once tought too exotic for North America. After the World Trade Center and Oklahoma City attacks, though, it became evident that the maximum precautions should be in place to protect North American nuclear sites. [Comment 1469, Source Document phpub034, Page 2]

Northwatch

the EIS should discuss accidental intrusion and criminal intervention ... and how accidental intrusion and criminal intervention are anticipated and responded to [Comment 1361, Source Document pub046, Page 11, Section d]

Science for Peace (Energy Working Group)

international supervison of repositories via satellite should be considered. It is important that the Canadian sites be kept under international inspection to enhance safety and security, and as an example to other nations.... The IAEA should be requested to place its own seals and monitors on the various components of the disposal system. [Comment 1717, Source Document ph2pub034, Page 5]

OPG RESPONSE

AECL's 1994 EIS discusses security and safeguards associated with the handling and transportation of used fuel (see PRD-Preclosure). The system is considered to meet the stringent requirements set out by the Canadian Nuclear Safety Commission and the International Atomic Energy Agency, and would adequately protect the public, transportation personnel and the environment from willful terrorist action, theft or sabotage.

AECL described an approach to applying nuclear materials safeguards and nuclear facilities security to the used-fuel repository presented in the EIS (see R-Facility). This was reviewed by CNSC staff and was judged to be an adequate approach for this conceptual design stage. The IAEA has not yet established requirements for applying safeguards to used-fuel repositories, although this is under development. The detailed design of a geologic repository would satisfy the security and safeguards requirements that are required by the CNSC at that time.

Finally, it should not be forgotten that the deep geologic repository inherently provides better security than used fuel stored on the surface.
6.12 Engineering - Quality Assurance

PARTICIPANT COMMENTS

Northwatch and Campaign for Nuclear Phaseout (Kreusch, Neumann, and Gruppe Ekologie)

develop ... evaluation methods (assessment criteria and comparison levels) for all protective material. It must actually be possible to obtain the data required for their use [Comment 1593, Source Document ph2tec044, Page 19, Section 6]

OPG RESPONSE

OPG has developed preliminary design requirements for the engineered barrier systems, and is using these as a guide for the on-going material research and development program. These will eventually lead to material specifications (as is happening in the Swedish and Finnish programs).

Within the quality assurance system established for the project, quality control procedures would be prepared for all testing activities that are being undertaken, including testing associated with the evaluation, acceptance, preparation and application of the engineered barrier (i.e., protective) materials. For example, AECL has become ISO 9001 certified, and so all work presently undertaken at the AECL Underground Research Laboratory is compliant with this quality assurance system

6.13 Engineering - Intrusion Resilience

PARTICIPANT COMMENTS

Canadian Coalition for Ecology, Ethics and Religion

The NRC recommend ... that the consequences of an intrusion be calculated to assess the resilience of the facility to it.... The NRC recommend that the facility "should be resilient to at least modest inadvertent intrusions".... We concur with these NRC recommendations and request their adoption here. [Comment 1856, Source Document ph2pub021, Page 56, Section 08.6]

Health Canada

The analysis of long-term effects indicate that total radiological risk is dominated by human intrusion scenarios.... the only factors that are considered in order to minimise such events is vault depth, and the avoidance of ore-bodies during vault siting. The EIS does not consider other factors, such as the size of the vault or the stacking of waste containers, that may either increase or decrease the risk or consequence of inadvertent intrusion. [Comment 945, Source Document gov006, Page 13]

OPG RESPONSE

AECL's 1994 EIS assessed the impact from intrusion into a deep geologic repository for 72-bundle containers and in-floor emplacement (see PRD-Postclosure). Both the probability and consequences have been evaluated. The probability of inadvertent human intrusion is considered to be low and is reduced with increasing depth of a geologic repository.

More recently, the human intrusion scenario is being re-evaluated for a different container and repository configuration (324-bundle containers and in-room emplacement) as part of the OPG Third Case Study (Gierszewski et al., 2004, in preparation). The results are generally similar to those observed in the AECL's 1994 EIS.

From these analyses, we can infer that that the details of the container or vault layout have little effect on the consequences of intrusion, and some effect but less than an order of magnitude on the probability of intrusion.

Gierszewski, P.G. et al. Third Case Study postclosure safety assessment, OPG Report 06819-REP-01200-10109-R00 (in preparation) 7 SAFETY ASSESSMENT

7.01.01 Safety Assessment - General - Integration of Assessments PARTICIPANT COMMENTS

Scientific Review Group

the complex linkages between the BIOTRAC sub-models and with the geosphere model GEONET, the pre-closure model PREAC, and the postclosure models (R-Biosphere 1994: pp.295-304) ... appear to show, collectively, rather independent approaches to different portions of a integrated problem. The end result runs a risk of the combination of models being a mathematical construction somewhat divorced from the reality of Nature. [Comment 413, Source Document tec004, Page 067, Section 6.4.2]

There is no indication that the parameters used in the two biosphere models, PREAC (preclosure) and BIOTRAC (postclosure), are compatible and provide a linkage where required [Comment 111, Source Document tec004, Page 148, Section D-2.1.15]

Some specific areas where preclosure assessment would require further development are: ... integration of important environmental impacts during preclosure that would have a bearing on the long-term performance of the concept (such as the use of similar parameters in modelling the environment; integration of the two biosphere models; the impact of surface biology in the subsurface; and groundwater contamination from surface sewage and waste rock pile). [Comment 134, Source Document tec004, Page 152, Section D-3]

It seems strange, and reflects on the credibility of the modelling, that the bases for the Preclosure Radiological Environmental Assessment Code (PREAC) and for BIOTRAC were not linked conceptually and more co-ordinated, early in the development of the disposal concept.... Such fragmentation may be a handicap to the acceptance and ultimately the successful implementation of the concept. [Comment 258, Source Document tec004, Page 229, Section H-2.1]

OPG RESPONSE

The nature of the processes important in the vault, geosphere and biosphere are different, and so there are good reasons why different models would be appropriate for each. And in the case of the biosphere, a difference between the pre- and post-closure models would also be reasonable because of the different time scales - for pre-closure there are specific communities that can be identified, whereas the post-closure must necessarily consider the impacts many years in the future when the current communities and biosphere will have altered in detail.

Nonetheless, it is certainly important that the models themselves and their linkages be well-described, and common parameters used where appropriate in future safety assessments. The possibility of using a common biosphere model (and/or datasets) will be considered.

7.01.02 Safety Assessment - General - Presentation of Risks

PARTICIPANT COMMENTS

Health Canada

In all cases, the results are described in terms of the dose to individuals, rather than in terms of risk per se. Collective radiation doses are presented in the results of the 'Preclosure Assessment' in Section 6.1.1.4 (p.6-30 and p.6-37), but risks per se are not presented. [Comment 923, Source Document gov006, Page 04]

in both the preclosure and postclosure assessments dose rates from background radiation are presented, rather that risks per se. [Comment 925, Source Document gov006, Page 04]

OPG RESPONSE

Dose rates are usually used to present the results of pre- and postclosure assessments, as is internationally common practice. In part, this is because dose rate is a relatively well defined and calculable quantity. The conversion between risk and dose can be made using the ICRP risk-to-dose conversion factor.

However, it is recognized that the CNSC criterion (R-104) is a risk-based criterion, and that some audiences prefer results presented in this form. Therefore, except for preclosure collective dose, the main results of the studies are also described in terms of risk in the conclusion of the EIS summary report (AECL 1994, p.319), in the conclusions of the Postclosure report (Goodwin et al. 1994, p.259) and in the executive summary of the Preclosure report (Grondin et al. 1994, p.xi).

References:

AECL. 1994. Environmental impact statement on the concept for disposal of Canada's nuclear fuel waste. AECL report AECL-10711, COG-93-1.

Goodwin, B. et al. 1994. The disposal of Canada's nuclear fuel waste: Postclosure assessment of a reference system. AECL report AECL-10717, COG-93-7.

Grondin, L., et al. 1994. The disposal of Canada's nuclear fuel waste: Preclosure assessment of a conceptual system. Ontario Hydro Nuclear report N-03784-940010 (UFMED), COG-93-6.

7.01.03 Safety Assessment - General - Baseline Data

PARTICIPANT COMMENTS

Canadian Coalition for Ecology, Ethics and Religion

the data base from actual testing must be expanded to reduce reliance on models and to generate better input for the necessary modelling. [Comment 1865, Source Document ph3pub160, Page 4]

Health Canada

There is no comprehensive description of current population sizes in the reference environments (only population densities) [Comment 935, Source Document gov006, Page 09]

Neither of these Sections in the main EIS document really address the guideline requirements to establish reference baselines for the physical and psychological health of the populations, despite the availability of actual data ... The Ontario Health Survey, conducted in 1990 by the Ontario Ministry of Health, collected data on the current health status of thousands of Ontarians, including their physical and psychological health. Another relevant source of data on health status in Ontario that has not been included is the three atlases published by the Great Lakes Health Effects Program on birth defects, cancer incidence and hospital morbidity in Ontario, respectively. [Comment 936, Source Document gov006, Page 09]

there is hardly any characterization of baseline community and social health. [Comment 937, Source Document gov006, Page 10]

the baseline chemical and radiochemical composition are not presented for surface or groundwater. [Comment 959, Source Document gov006, Page 16]

because siting operations will include excavation operations which inevitably may dislodge mercury from soils and rock formations and therefore favour the formation of methyl mercury in aquatic environments surrounding the sites, there may be a need to add mercury in fish to the list of background contaminants that should be measured before any construction and during the monitoring schemes planned during preclosure and postclosure assessments. [Comment 1007, Source Document ph2gov011, Page 15]

There is a need for appropriate baseline studies before the operation, and monitoring during and after the operation of the project. Human health surveys are commonly requested by native communities which are sensitive to disruption from increased commercial activity. It will be important to have some idea of the incidence of radiation related cancers among the resident native population particularly the children. Dietary Surveys which include country foods of vegetation, plants and berries used for consumption, band traditional medicines, food sources (animal and vegetable and fish which are consumed) should be undertaken. [Comment 1013, Source Document ph2gov011, Page 17]

Inter-Church Uranium Committee (Fortugno)

The essential developmental tasks which must first be accomplished in Canada include ... preparation of comprehensive baseline studies on the health of humans and other biota in the potential siting regions (i.e., the Canadian Shield) [Comment 2106, Source Document ph2pub031, Page 7, Section V]

The essential developmental tasks which must first be accomplished in Canada include ... preparation of a national inventory of environmentally sensitive and "valuable" regions [Comment 2107, Source Document ph2pub031, Page 7, Section V]

McMaster Institute for Energy Studies

The location, abundance, scientific importance or even physical characteristics of wetlands is not described. Considering their importance and the availability of a wealth of knowledge pertaining to them, a map of significant wetlands should have been included as well as a more detailed analysis of wetland ecosystems. [Comment 1434, Source Document phpub033, Page 14]

There are no graphic representations of the vegetation typical of the various regions. There are not tables, even in the appendices, which list all of the plant/tree species of the Ontario Canadian Shield. A study by Grondin and Fearn-Duffy (1993) is cited; however, the data is not made available nor even summarized. This is data that is readily available through university databases and, consequently, should have been included for public review. While the geographic area occupied by the Ontario portion of the Canadian shield is indeed significant, the region could have been divided into zones where the vegetation typical of the region could have been summarized. [Comment 1435, Source Document phpub033, Page 15]

Concepts such as population composition, population distribution and species abundance are essential components of ecosystem analysis. General numbers of species, their relative abundance and distribution should have been provided either in the form of a table or a map for easy review. [Comment 1436, Source Document phpub033, Page 15]

it is stated that, "... sixty-two species of flora and fauna have been recorded as being rare, threatened or endangered on the Canadian Shield in Ontario". The identity and location of these species is not provided in the EIS.... it is important that the public be made aware of the specific species and their distribution so as to allow informed input from the public when deciding upon exclusion criteria. [Comment 1439, Source Document phpub033, Page 16]

Northwatch

the EIS is inadequate in its description of the terrestrial ecosystems; for example there is no discussion of species association, species composition and age class structure in the forest types, patterns of natural disturbance, forest ecosystem classifications, ecotones, old growth ecosystem types, areas of natural and scientific interest; [Comment 1368, Source Document pub046, Page 14, Section d]

OPG RESPONSE

If disposal is selected by the federal government as the preferred option, then siting would likely proceed in a staged approach and these comments would naturally be addressed. For example, possible siting areas would likely be identified based on a variety of criteria, including ecological sensitivity. Specific candidate sites would be characterized better, including baseline data on the local environment and local populations. And any selected site would likely start with an underground test facility that would provide specific site-relevant data to support models.

7.01.04 Safety Assessment - General - Assessment of Rare Events

PARTICIPANT COMMENTS

Ontario Association for Environmental Ethics

rare events should be examined deterministically whenever possible even when only partial information is at hand because a critical factor may suggest a different degree of certainty than would a frequency measure expressed relative to time. [Comment 1632, Source Document phpub088, Page 28]

the temporal distribution of rare events can be assessed and the time frame of the event's expected occurrence (e.g. 8 every million years) can be compared with the time frame of concern (e.g. 10,000 or 100,000 years for nuclear waste management) to provide either a more accurate measure of risk (uncertainty) or greater confidence in a measure. [Comment 1633, Source Document phpub088, Page 28]

OPG RESPONSE

The complete submission associated with these comments discusses a number of topics with respect to the language of risk and the definitions of probability. The suggestion in the first comment above is not clear. The other comment recommends a preferred method to describe the occurrence of rare events. We would wish to consult with experts in risk assessment closer to the time of an actual siting effort so that our definitions and usage was acceptable with current standards. However, we expect that risk would need to be expressed in different methods in any event, since ways to communicate with non-technical audiences may be different than those for the technical risk assessment community.

7.02

7.02.01 Safety Assessment - Preclosure - Methodology

PARTICIPANT COMMENTS

Atomic Energy Control Board

Potential impacts on aquatic and terrestrial organisms of the release of toxic chemicals should also be assessed based on their toxicity using pathways analysis and hazard quotients (ecological risk assessment) (Preclosure PRD, p. 6-109). [Comment 672, Source Document gov002, Page 74, Section D.2.1]

The method used to calculate whole body and thyroid doses for accident scenarios should have been provided. [Comment 675, Source Document gov002, Page 75, Section D.2.4]

Environment Canada

Three typical sites, reference environments and transportation routes were considered for the preclosure assessment. These ... receive only cursory characterization with respect to non-human biota.... There are no distribution or population characteristics for typical species such that effects from habitat loss or increased public access could be estimated. [Comment 883, Source Document gov003, Page 30, Section 2.14]

Scientific Review Group

The approach taken to describe the natural environment precludes an ability to identify all potential effects. [Comment 470, Source Document tec004, Page 094, Section 7.5]

The information contained in this document does not fulfil the basic requirements of an environmental impact assessment, not even from a conceptual point of view Much of the material in R-Preclosure concerning how the natural environment will be represented, and how the impacts will be determined, is presented only in very general terms. Such an approach will not describe the environment in an effective and practical manner, and makes it difficult to judge how effectively the environment is considered in preclosure assessment, which sensitivity analyses can be performed, how environmental protection regulations will be met, and what useful knowledge and information will be passed on.... A more complete, effective and co-ordinated understanding of environmental issues in preclosure assessment guidelines and procedures ... Hazard charts ... could also have been applied to the natural environment. [Comment 117, Source Document tec004, Page 148, Section D-2.2.1]

guidelines and analytical methods that could be used in the assessment of disposal ... activities at the site-specific stage ... have not been explicitly expressed. [Comment 133, Source Document tec004, Page 152, Section D-3]

OPG RESPONSE

It is expected that any formal license application would require an environmental assessment. It is anticipated that the preclosure portion of the assessment would be relatively standard, and would draw on experience with nuclear power plants, uranium mines and other relevant facilities. The preclosure portion would be carried out using acceptable methods and tools in use at that time (e.g. ecological risk assessment methods have matured since the early 1990's when the AECL EIS was prepared). It is quite possible that the preclosure portion of the assessment would be substantially completed by a contractor with current experience in carrying out such studies for other similar scale projects.

7.02.02

Safety Assessment - Preclosure - Models

7.02.02.01 Safety Assessment - Preclosure - Models - Verification and Validation

PARTICIPANT COMMENTS

Atomic Energy Control Board

Validation activities have not been carried out for the computer codes used to assess the potential radiological and toxic chemical impacts on the environment from the operations of the disposal facility (PREAC, PSAC, and CEMTOX) [Comment 677, Source Document gov002, Page 76, Section D.3.1]

Scientific Review Group

Model validation is missing The preclosure assessment models are based on Ontario Hydro quality assurance procedures, which are not clearly shown to have been validated (R-Preclosure 1994: p.1-23).... The use of Ecosystem Stress Models as decision-making tools to compare alternative site is discussed (R-Preclosure 1994: p.10-6). Information about the state of advancement of these models, their reliability and ensuring validation should also have been provided. [Comment 101, Source Document tec004, Page 146, Section D-2.1.2]

OPG RESPONSE

See the response to the previous comments (7.02.01). Use of currently accepted codes and standards would be expected in any future preclosure environmental assessment.

7.02.02.02 Safety Assessment - Preclosure - Models - Probabilistic PARTICIPANT COMMENTS

Scientific Review Group

The risk modelling process is deterministic in principle and is insufficient by current standards ... A probabilistic analysis satisfying, as a minimum, Canadian Standard CSA Q-634-1991 (CSA 1991) for risk assessment could have been provided, thereby creating, a coherence between this preclosure assessment and long-term risk assessment ... Uncertainties in the processes and their modelling should have been accounted for. [Comment 118, Source Document tec004, Page 148, Section D-2.2.2]

OPG RESPONSE

See the response for the previous comments #7.02.01 .

7.02.03 Safety Assessment - Preclosure - Case Studies

PARTICIPANT COMMENTS

Concerned Citizens of Renfrew County and Area

Estimates of exposures provided in the EIS should have been validated using CRL data for both normal operating conditions and accident scenarios. [Comment 1982, Source Document ph3pub216, Page 05]

The EIS should have also calculated health outcomes and costs associated with estimated radiation exposure levels.... studies of CRL workers,... would provide data on actual health impacts of an operating nuclear facility that could be compared to calculated health outcomes. [Comment 1983, Source Document ph3pub216, Page 05]

Environment Canada

The duration of exposure assumptions in accident scenarios seem optimistic and are not supported by reference to any analysis of actual incidents, especially in the analysis of doses to workers. [Comment 880, Source Document gov003, Page 30, Section 2.14]

Health Canada

the proponent does not include the epidemiological studies of low--level exposure to ionizing radiation as case studies ... some of the low dose studies may be useful as case studies. These include occupational studies of nuclear power plant workers, and studies of exposed military personnel, people living downwind of nuclear facilities and people exposed to ionizing radiation for therapeutic reasons.... studies of people living in areas of high natural background radiation (Espirito Santo, Brazil; Kerala, India; and Yangjiang, China) ... epidemiological studies of lung cancer in miners (especially uranium miners) ... The proponent should explain why these and other studies have not been more extensively discussed and used as case studies [Comment 926, Source Document gov006, Page 05]

There is a need for ... More information on the cumulative effects of other operations of a similar nature. [Comment 1012, Source Document ph2gov011, Page 17]

National Action Committee on the Status of Women

none of the historical and current impacts of uranium mining and nuclear waste disposal on Aboriginal peoples described above and elsewhere are discussed in the EIS. [Comment 1303, Source Document pub026, Page 38, Section 7.5.2]

Natural Resources Canada

In total, neither sections 6.6 - 6 11 nor R-Preclosure completely meet the requirements of the guidelines with respect to case studies. The EIS (including primary references) does not clearly determine major indicators that would signal impacts, it does not conclude what can be learned with respect to social, economic and environmental impact of the disposal operation. The EIS ...does not, as required by the guidelines, present impact comparisons with commercial analogues such as uranium mines or toxic waste management facilities.... An analysis of the causes of accidents during mine or other major underground construction, together with plans for different approaches proposed for the disposal facility, could present a convincing case. Similar arguments apply to the EIS discussion of the impact of operations. [Comment 712, Source Document gov005, Page 31, Section 8.21]

Scientific Review Group

Relative severities of impacts resulting from site characterization and construction of the nuclear fuel waste facility are not treated in depth.... There is no indication of the severity of the potential impact, although it has been standard practice in environmental impact statements since the 1970's to indicate the severity by terms such as minor, moderate, or severe where these terms are always carefully defined.... it should have been possible to derive generic degrees of impacts based upon past experience with similar large projects such as uranium mines.... Case studies addressing the environmental impact of facility construction on surface water quality are not used as a reference.... The impact of increased accessibility arising from construction of a major facility is not considered in depth..... This is of concern because experience with developments in other remote, northern locations has shown that the most dramatic impacts on fish and wildlife are often due to road construction followed by increased hunting and fishing pressure. [Comment 119, Source Document tec004, Page 148, Section D-2.2.3]

The document states: "Soil stability may be altered as a result of waste rock disposal" (R-Preclosure 1994: p.6-98). However, there are no estimates as to the degree to which the soil stability will be altered. The operation phase will last a long time - what will be the overall impact on soil stability over this time period? What mitigation measures would be indicated? What are the relevant case histories from large mining operations in the Canadian Shield? [Comment 126, Source Document tec004, Page 150, Section D-2.2.5]

The environmental impacts from decommissioning are not set out.... some ranking of concerns based on previous experience at other nuclear facilities would have been helpful [Comment 127, Source Document tec004, Page 150, Section D-2.2.5]

OPG RESPONSE

These comments suggest a number of areas where better information could be provided for the preclosure portion of an environmental assessment. As noted in earlier comments (#7.02.01), it is expected that any future environmental assessment would be carried out using then-current methods and tools, and draw on the available case studies and epidemiological information as appropriate.

7.02.04 Safety Assessment - Preclosure - Quality Assurance

PARTICIPANT COMMENTS

Environment Canada

Numerous minor deficiencies have been identified in the preclosure QA/QC program. The majority of these can be corrected through better documentation as follows: validation, where possible, of code predictions with actual field measurements; integrated uncertainty analysis using probabilistic codes ...; documentation of participation in model inter-comparison studies; documentation of all input parameters [Comment 892, Source Document gov003, Page 35, Section 2.16]

OPG RESPONSE

See the response to comment #7.02.01.

7.02.05 Safety Assessment - Preclosure - Sensitivity Analysis

PARTICIPANT COMMENTS

Health Canada

Section 6.13.1 lists several important factors which can affect the sensitivity of the estimations provided. The description is terse and offers few quantitative results (it offers no measures of variability of estimates). [Comment 975, Source Document gov006, Page 22]

OPG RESPONSE

See response to comment #7.02.01.

7.02.06 Safety Assessment - Preclosure - Presentation of Results

7.02.06.01 Safety Assessment - Preclosure - Presentation of Results -Residual Effects

PARTICIPANT COMMENTS

Scientific Review Group

R-Preclosure does not provide sufficient detail on ... residual effects following mitigative measures. [Comment 115, Source Document tec004, Page 148, Section D-2.1.16]

OPG RESPONSE

See response to comment #7.02.01.

7.02.06.02 Safety Assessment - Preclosure - Presentation of Results -Significance

PARTICIPANT COMMENTS

Atomic Energy Control Board

Predicted thyroid doses and whole body doses should be compared to their respective limits or guidelines, and not to each other. [Comment 905, Source Document gov002, Page 75, Section D.2.4]

Environment Canada

Temporal and spatial scales of analysis in the preclosure assessment are generally given but are not well linked to statements of dose and risk. This is considered to be a major deficiency. [Comment 879, Source Document gov003, Page 30, Section 2.14]

Health Canada

significance could be evaluated by comparisons with requirements in legislation, regulatory documents and guidelines; by comparison with background levels; by comparison with industrial standards and by consultation with the potentially affected communities. It is unclear, however, how these different factors and ways of evaluating significance will be combined together in any environmental assessments related to concept implementation. [Comment 928, Source Document gov006, Page 06]

Some discussion of radiological and non-radiological hazards to workers is provided, however there is no information about the related risks (i.e. consequences are noted without consideration of probabilities). [Comment 974, Source Document gov006, Page 21]

McMaster Institute for Energy Studies

There is also a tendency to trivialize or minimize potential impacts.... Statements must be quantified and qualified. It is not appropriate for the proponent of make blanket statements in an environmental impact statement requiring the specifics of potential impacts. [Comment 1443, Source Document phpub033, Page 19]

Scientific Review Group

The significance of potential effects (e.g. socio-economic and natural environmental effects) to the extent possible without the identification of a disposal site and the participation of potentially affected communities is not indicated.... for residual environmental effects ... relative significance is not presented. [Comment 471, Source Document tec004, Page 094, Section 7.5]

The significance of residual environmental effects cannot be assessed on the basis of the description given of the environment. Ontario Hydro has demonstrated a method for assessing significance of residual safety hazards, but this method was found deficient and incomplete in numerous respects. [Comment 132, Source Document tec004, Page 152, Section D-3]

OPG RESPONSE

These comments identify points where the presentation of preclosure results was felt by the reviewers to be inadequate. These will be reviewed as part of the preparation of any future preclosure assessments.

7.02.07 Safety Assessment - Preclosure - Effects on Workers

PARTICIPANT COMMENTS

Campaign for Nuclear Phaseout

There is very little attention paid to cask handling or to the transfer of fuel rods from one container to another and radiation exposure during the period when the wastes are unshielded. [Comment 1786, Source Document pub027, Page 22, Section III.C]

No estimate is provided of how radiation levels will increase during the operating life of the disposal facility. [Comment 1821, Source Document pub027, Page 35, Section III.H]

Methods for calculating accident probabilities and radiation exposures at disposal facilities are not well detailed. [Comment 1824, Source Document pub027, Page 35, Section III.H]

While the EIS provides estimates for radiation exposure to the public in the event of a ventilation system failure, no estimates are provided for exposure levels for underground workers. [Comment 1825, Source Document pub027, Page 36, Section III.H]

Concerned Citizens of Renfrew County

Insufficient data are provided in the HLW EIS and supporting documents to verify estimates of worker exposures, particularly for accident scenarios. [Comment 1971, Source Document phpub171, Page 2]

Concerned Citizens of Renfrew County and Area

The EIS does not adequately address the issue of worker health and safety.... The EIS does not discuss radioactive emissions and exposures associated with routine operation and maintenance of the fuel waste packaging facility.... the methodology for calculating [probabilities of accidents] and resultant radiation exposures is not described. The EIS (p. 243) provides a table for estimating doses to the public for six accident scenarios, but does not provide an equivalent table for workers.... Accident scenarios are described in such vague terms that this is impossible to determine if [breaking of containers during an accident] was considered. It is also not clear whether estimates of accident-related worker exposures include clean-up activities. The EIS does not address the issue of increasing radiation levels at the facility during its estimated 41-year operating life, and impacts of this increased radiation on worker exposure levels. [Comment 1978, Source Document ph3pub216, Page 04]

National Action Committee on the Status of Women

How will increasing levels of radiation as the repository is filled affect workers who are involved in waste emplacement? [Comment 1297, Source Document pub026, Page 34, Section 7.3.3]

How will increasing temperatures as a result of growing volumes of waste affect working conditions? [Comment 1298, Source Document pub026, Page 34, Section 7.3.3]

How is the transfer of waste to take place on site from transport containers to storage containers? What exposure levels to both workers and the public are associated with this activity? [Comment 1299, Source Document pub026, Page 34, Section 7.3.3]

National Council of Women of Canada

there is no mention of possible radiation risks to those workers doing the actual work of transporting and handling the fuel wastes. [Comment 1323, Source Document phpub035, Page 04]

OPG RESPONSE

OPG has developed preliminary design requirements for handling used fuel in the packaging plant,

container shielding cask and emplacement rooms. For example, the used fuel container design must limit the container surface dose rate to below 15 Gy/h. OPG's container screening studies have specified a maximum dose rate on the container shielding cask to be 10 micro-Sv/h. OPG studies have been initiated to determine the maximum thickness of vault sealing materials and rock to reduce dose rates to 1 micro-Sv/h.

7.02.08 Safety Assessment - Preclosure - Cradle to Grave Materials Analysis

PARTICIPANT COMMENTS

Campaign for Nuclear Phaseout

The EIS should be revised to include a comprehensive discussion of the impact of all the materials that will be used in the repository's creation, including materials extraction/ production and transportation. In other words there should be a "cradle to grave" discussion of the repository which includes an analysis of all materials used, and their interactions. [Comment 1809, Source Document pub027, Page 27, Section III.F]

I'Union Sain-Laurent Grands Lacs

Le promoteur se contente d'analyser le concept sans le placer dans une perspective de cycle de vie qui permettrait par exemple, d'évaluer les impacts indirects, tel les quantités phenoménales de matériaux nécessaire à la construction du site.

[The concept was analyzed without a complete life cycle perspective which would have allowed, for example, evaluation of indirect impacts such as those related to the extraordinary quantities of material needed for construction.] [Comment 1466, Source Document ph3pub194, Page 4]

Mouvement Vert - Mauricie

These figures imply there will be a major impact on the mining industries involved. Vast quantities of cement, asphalt, sand, gravel, steel, silica, bentonite and clay will also be needed. Extracting and processing these raw materials has a major environmental impact. The supply of raw materials in any industrial or commercial activity creates a direct impact. Examination of the project's impacts must cover the entire cycle, and thus include the production of raw materials.... In particular, the MVM would like to know:

- whether new copper or titanium mines would have to be opened, or old ones expanded;

- whether new sand pits, gravel pits, and clay and bentonite extraction sites would have to be opened, or old ones expanded;

- whether new processing facilities would have to be established;

- the most probable location of these new facilities;

- in general, yet quantifiable terms, the impacts of these various facilities ...

- how these quantities would vary with the thickness of the shell of the fuel container. [Comment 1491, Source Document pub024, Page 28, Section 2.4.4]

Northwatch

the EIS should include a discussion of the at-source and transportation impacts of all the materials that will be used in the repository's creation, including the materials' extraction/production and transportation; this should form part of a "cradle to grave" analysis of the impacts of the repository's construction [Comment 1385, Source Document pub046, Page 16, Section d]

Nuclear Awareness Project

[Do] an analysis of the "front-end" processes required to implement the concept, including all resource extraction and processing required for all the constituent materials [Comment 1609, Source Document pub035, Page 7, Section D]

People Against Lepreau 2

We request a "cradle to the grave" analysis of the repository. The EIS should include discussion of the impact of all materials to be used in the creation of a repository, including materials extraction / production and transportation. [Comment 1637, Source Document pub018, Page 2]

OPG RESPONSE

AECL's 1994 EIS discusses the effects of resources, including non-renewable resources that may have to be removed from the geologic repository facility and further managed following applicable federal and provincial legislation (see PRD-Preclosure).

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7.03.01.01 Safety Assessment - Postclosure - Methodology - General PARTICIPANT COMMENTS

Campaign for Nuclear Phaseout

The EIS should incorporate the findings of recent independent work. Two studies which have direct relevance to technical issues discussed in the EIS are:

- K.S. Shrader-Frechette, Burying Uncertainty - Risk and the Case Against Geological Disposal - Regina I. Hunter and C. John Mann, eds., Techniques for Determining Probabilities of Geologic Events and Processes [Comment 1810, Source Document pub027, Page 28, Section III.F]

Ecosystem Approach Group

The methodology to evaluate the safety of a disposal system has not been demonstrated. [Comment 2044, Source Document pub033, Page 12]

Natural Resources Canada

The EIS does not fully respond to the requirements of the guidelines to compare the procedures for performance assessment of the disposal vault with procedures used in other countries.... the EIS does not offer a clear comparison and does not outline the advantages and disadvantages of differing approaches as required by the guidelines [Comment 710, Source Document gov005, Page 16, Section 6.5]

OECD/NEA Review Group

The Group believes that the EIS documentation does not adequately reflect the status of Canadian performance assessment methodology relative to that in other countries. Attention should be drawn to the pioneering step forward taken by AECL in the development of the SYVAC code and the probabilistic approach to safety assessment. SYVAC has a high profile internationally and has been used in a number of other programmes (e.g. Sweden, UK); [Comment 1222, Source Document tec001, Page 13, Section 4.2]

Scientific Review Group

future development of performance assessment methodology would have to be refocussed toward three-dimensional modelling by combining existing models with state-of-the-art numerical techniques and using the most modern computing equipment. [Comment 387, Source Document tec004, Page 057, Section 6.3.1]

the SRG questions the basic SYVAC methodology which consistently analyzes geosphere and biosphere transport processes together in the SYVAC scenario and sensitivity analyses. The processes in these two systems operate at different time scales and different levels of complexity. AECL should have considered alternative approaches to allow a better focus on the respective parameters that control transport in each of the two different systems. For example, decoupling the geosphere and biosphere transport processes in the scenario and sensitivity analyses might have achieved this objective while reducing the overall number of scenarios and improving the efficiency of the procedure. [Comment 447, Source Document tec004, Page 081, Section 6.6.3]

New state-of-the-art tools for the analysis of complex groundwater systems have recently been developed or are now being developed in other countries.... These or similar technologies ... should be closely examined. [Comment 541, Source Document tec004a, Page 18, Section 3]

At [the site evaluation] stage, it will be necessary to ensure that conceptual models used in the safety assessment receive broad input and review from a wide variety of stakeholders. The conceptual models must be robust and well accepted before proceeding to quantitative analysis. [Comment 547, Source Document tec004a, Page 19, Section 3]

OPG RESPONSE

The methodology for long-term safety assessment has been evolving slowly, and there is no one correct method. Although the EIS may not have formally compared the procedures with other countries, the OECD/NEA review of the EIS provides some assurance that the EIS methodology was reasonable according to international practice (e.g. see comment #4).

OPG remains very interested in international developments in safety assessment methodology, and would use current practices in any future assessment. We have also read the references given in Comment#1. [The first reference, although focussed on Yucca Mtn as of 1993, contains a number of questions that can be asked of a safety assessment; the second is a general discussion of determining geologic probabilities that would likely be superceded by current and site-specific information.]

OPG ensures that its methods are current in part through participation in the OECD/NEA radioactive waste program, which provides a forum for exchange of information between groups working in this area. Since the EIS (and the 1996 Second Case Study) were issued, there have been several workshops on methodologies and lessons learned from international postclosure safety assessments. Recent reports from OECD/NEA working groups (in which OPG participated) include:

OECD/NEA, 1997. Lessons learnt from Ten Performance Assessment Studies. OECD, Paris, France.

OECD/NEA, 1999. Confidence in the long-term safety of deep geological repositories. OECD, Paris, France.

OECD/NEA, 2000. Regulatory reviews of assessments of deep geologic repositories. OECD, Paris, France.

OECD/NEA, 2000. Features, Events and Processes (FEPs) for geologic disposal of radioactive waste. OECD, Paris, France.

OECD/NEA, 2001. Scenario development methods and practice. OECD, Paris, France.

OPG has also conducted independent reviews of its geosphere and vault models, in order to help determine the specific directions for improvement. One recommendation that we are presently testing is increased use of 3-D models to represent the vault and geosphere (see Comment #5).

Other examples where the Canadian safety assessment methodology has changed include:

- Scenario analysis - OPG has revised its FEPs (scenario) list to correspond with the OECD/NEA format, so that Canadian conclusions can be more readily compared with those used by other national waste management groups.

- Alternative models - OPG has developed two alternative safety assessment system models to help provide multiple lines of reasoning.

- Geosphere models - OPG is developing closer ties betweent the site characterization models and the safety assessment models.

Finally, we disagree somewhat with Comment #6. We think that an important result from a system model is that the uncertainties are put into overall context - do they affect the bottom-line impacts of concern or not. This requires that all processes be treated within a single model. We intend to continue to develop and apply such an integrated model. However, we do recognize that there is interest and value in understanding processes within particular submodels. It is likely that any future safety assessment will present a range of analyses including but not limited to a large set of system-level probabilistic runs.

7.03.01.02 Safety Assessment - Postclosure - Methodology - Scenario Analysis

7.03.01.02.01 Safety Assessment - Postclosure - Methodology - Scenario Analysis - General

PARTICIPANT COMMENTS

Canadian Coalition for Nuclear Responsibility (Regroupement pour la surveillance du nucléaire)

it seems unprofessional, unscientific, and ethically wrong to say that factors which are explicitly not included in a mathematical model are "implicitly included" just because the real world is experiencing these influences and therefore the data used as input parameter values for the model have been conditioned by those factors. [Comment 1894, Source Document pub049, Page 40]

Northwatch and Campaign for Nuclear Phaseout (Kreusch, Neumann, and Gruppe Ekologie)

The fundamental problem in the development and selection of scenarios arises from the long time frame that has to be considered. Because of this time frame it is almost impossible to make sure that all relevant or possible events (and of course any combination of events) have been recognized and described properly. [Comment 1576, Source Document ph2tec044, Page 05, Section 2.2]

OECD/NEA Review Group

The scenario selection methodology ruled out scenarios which may have been instructive to analyse. Further testing of the scenario methodology over future years is recommended. [Comment 1234, Source Document tec001, Page 14, Section 4.3]

Scientific Review Group

AECL's Scenario Analysis The general methodology used by AECL conforms with standard practice ... However, the application of this general methodology is not described in sufficient detail to allow a thorough evaluation of the resulting three scenarios used by AECL. ... The use of tools such as influence diagrams and fault/event trees is seldom referred to in the postclosure assessment. It would be expected that narrative screening arguments alone would not be sufficient cause to eliminate a factor. The absence of detailed screening arguments from either the Postclosure Assessment document or other Primary References creates concern that some arguable selection mechanisms might have been used to eliminate factors [Comment 146, Source Document tec004, Page 169, Section E-2.1.4]

it would have been good practice to have tested the sensitivity of the results to some of the screenedout factors before leaving them completely out of further consideration [Comment 156, Source Document tec004, Page 170, Section E-2.1.4]

OPG RESPONSE

It is clearly desirable that the scenario selection procedure be objective, transparent and traceable. OPG has reviewed possible procedures, including the EIS approach as well as those used internationally. This topic was also addressed at a 1999 NEA sponsored workshop on Scenario Development Methods and Practices (NEA 2001). A key conclusion is that the process will continue to rely on expert judgement.

However, the results can be improved by checking the assessment of factors and of scenarios, including comparisons with similar international studies; by seeking feedback from the CNSC and other stakeholders to ensure that scenarios of special interest have not been overlooked; and by fully documenting the selection process.

In advance of an actual siting process, OPG is revising the FEP database. A Microsoft Access database is being prepared that will form the basis for a more searchable and traceable Canadian FEP

database. It is structured along the lines of the NEA International FEP database, rather than that used by AECL for the EIS, so that the specific FEPs developed or screened for any future Canadian safety assessment may be more directly compared with the screening in other international safety assessments (e.g. NEA 2000). OPG is a supporting member of a group of NEA countries that are contributing their safety assessments to this NEA reference database.

Finally, some specific comment responses:

- Implicit treatment of factors - The new database should provide a more substantive discussion of such factors, and comparison with what is accepted in other national assessments.

- Sensitivity of results to screened out factors - The decision to screen out certain factors will be based on a variety of arguments, ranging from expert judgement to actual calculations. We intend to make the screening basis more transparent in future (e.g. via the FEPs database), so that reviewers can more readily identify any factors that they believe warrant further analysis.

References:

NEA. 2001. Scenario development, methods and practice. OECD report. Paris, France.

NEA. 2000. Features, Events and Processes (FEPs) for geologic disposal of radioactive waste. OECD report. Paris, France.

7.03.01.02.02 Safety Assessment - Postclosure - Methodology - Scenario Analysis - Participants

PARTICIPANT COMMENTS

Scientific Review Group

Expert judgement obviously played a major role in AECL's scenario analysis, yet the experts who contributed to the development of the initial list of factors and the screening arguments were not identified, nor were their qualifications given. [Comment 432, Source Document tec004, Page 078, Section 6.6.2]

the list of experts (R-Postclosure 1994: p.49) does not include disciplines such as nuclear medicine, demography, economics, sociology, history, anthropology, and ethics [Comment 433, Source Document tec004, Page 078, Section 6.6.2]

non-expert stakeholders are not mentioned as part of the group that initially developed and then screened factors. [Comment 434, Source Document tec004, Page 078, Section 6.6.2]

OPG RESPONSE

The factors or "FEPs" list has being significantly updated for the OPG Third Case Study project. The FEPs are now documented in a Microsoft 2000 Access database that contains the screening analyses for any given OPG deep geologic repository safety assessment. The FEPs themselves are organized from an international FEPs list that was developed collaboratively among several national nuclear waste management organizations (NEA). Use of this international basis ensures that the OPG list is comprehensive.

The OPG FEP database includes provision for entering who contributed to the analysis and review, and for a brief statement of their qualifications.

A listing of the main information in the FEPs Database for the Third Case Study is available in Garisto et al. (in prep.). It is expected that the FEPs database and screening analysis will continue to improve based on internal studies and ongoing comparison with the international database, of which OPG is a continuing partner.

References

Garisto, F., P. Gierszewski and K. Wei. 2003. Third Case Study - Features, Events and Processes. OPG Report 06819-REP-01200-10125-R00 (In preparation).

NEA. 2000. Features, events and processes (FEPs) for geologic disposal of radioactive waste. OECD/NEA report.

7.03.01.02.03 Safety Assessment - Postclosure - Methodology - Scenario Analysis - Screening Criteria

PARTICIPANT COMMENTS

Canadian Coalition for Nuclear Responsibility (Regroupement pour la surveillance du nucléaire)

The proponent should be required to deal with the consequences of factors which could have significant implications for the Geological Burial Concept, regardless of the proponent's opinion that they are unlikely to come into play in the next 10,000 years. The possible consequences of each of the following factors, over the next few millenia, should be explored in sufficient detail to understand the implications 1) for the buried nuclear fuel waste, and 2) for the assumptions on which each of the computerized mathematical models used in post-closure assessment is based - accidental criticality in the vault; microbial action; gas generation; glaciation; topographic change; biosphere evolution; climate change; open boreholes; earthquakes; meteorites. [Comment 1898, Source Document pub049, Page 42]

Scientific Review Group

A factor having a low probability of occurring does not necessarily make it an automatic candidate for omission. The interest of the public will certainly be focused on some worse cases scenarios. The current screening for scenario analysis is not applicable to worst case [Comment 155, Source Document tec004, Page 170, Section E-2.1.4]

[Regarding screening arguments] (1) what if guidelines or regulations do not exist for a particular chemical contaminant? (2) What if non-human biota are much more sensitive than humans to a particular chemical contaminant? (3) What if there are no guidelines for non-human biota and there are insufficient toxicological information to interpret what incremental concentrations above background would be harmful? [Comment 161, Source Document tec004, Page 173, Section E-2.1.5]

OPG RESPONSE

It is expected that any future siting-related safety assessment will include evaluation of a number of 'what-if' scenarios, in addition to any probabilistic studies. The selection of these scenarios will depend in part on consultation with stakeholders.

Regarding Comment#3 in particular, there have been (and are still ongoing) developments in guidelines for chermical contaminants and for handling non-human biota since the EIS. We anticipate that there would be a reasonable basis for assessing these questions at the time of any future safety assessment.

7.03.01.03 Safety Assessment - Postclosure - Methodology - Analogs PARTICIPANT COMMENTS

Atomic Energy Control Board

The EIS does not make adequate use of natural analogues to support the long-term simulation results, or to identify desirable and undesirable site characteristics.... The only natural analogues of the disposal concept that are invoked are the Cigar Lake uranium deposit and the Oklo natural reactors (Vault PRD, pp. 156-159). Other analogues, that do and do not demonstrate containment, are ignored.... The limitations of the natural (and one anthropogenic) analogues that are cited for clay seals in the vault are not taken into account.... Although some analogues for used fuel dissolution and for bentonite barriers are presented to support parts of the vault model (Vault PRD, p. 247), there are no analogues at all for the container corrosion models.... Confidence in AECL's predictions of long-term corrosion behaviour of titanium containers would be enhanced if they had cited some analogues (such as predictions of corrosion in reactors), or even if they had applied the same approach to better known and verifiable systems (e.g., predictions of the lifetime of steel drums based on the known corrosion mechanisms of steel). [Comment 570, Source Document gov002, Page 23, Section A.6.5]

Canadian Geoscience Council

numerous analog studies should be encouraged, although their impact should be carefully evaluated because there will be important geologic differences between natural deposits and disposal sites.... [The Cigar Lake Analog study] contains almost no structural geology, is restricted to only one deposit, relies on geochemical data that has not yet been reviewed by the scientific community, and is a much better analog for studying processes than for engineering.... The thermodynamic data bases are old (1966, 1979). Attention should be paid to modern data bases.... It was not clear from the report if the hydrogeological effects were appropriate to the present groundwater regime, to the original, deeper one, or to something in between. [Comment 1066, Source Document tec002, Page 26, Section 4.2]

natural analog studies present a quandary, because some deposits have been totally remobilized by groundwaters, and the material has therefore disappeared and the deposits can no longer be studied. Others have been less affected. These latter remain "deposits", like Cigar Lake. But, the deposits that remain offer only limited information about the effect of groundwaters for the exact reason that they have not disappeared! This argument is not meant to invalidate doing natural analog studies, but to emphasize their ambiguous, and sometimes limited nature. The studies must be combined with theoretical and laboratory data and models. [Comment 1072, Source Document tec002, Page 27, Section 4.2.1]

Studies of ancient fracture systems and the chemical migrations accompanying them may help verify some aspects of the hydrogeologic models. Studies of ground water isotopes and chemical constitutents could be used for tracer purposes. Studies of the progress of alteration in open fractures may reveal time histories. Studies of natural analogues will illuminate at least selected aspects of processes. [Comment 1074, Source Document tec002, Page 28, Section 5.1]

Joint Committee of the Canadian Academy of Engineering and the Royal Society of Canada

Very little use appears to have been made by AECL of analogue models other than the Cigar Lake analogue study (Ref. 9, p.16). [Comment 1150, Source Document tec003, Page w08, Section 7]

Northwatch and Campaign for Nuclear Phaseout (Kreusch, Neumann, and Gruppe Ekologie)

the value of natural analogues is limited. Because of their characteristics as "uncontrolled natural experiments" the peripheral conditions as well as other important parameters in natural analogues are very often unknown. Therefore, results gained from natural analogues are not a substitute for the necessary validation of models. [Comment 1578, Source Document ph2tec044, Page 06, Section 2.2]

OPG RESPONSE

We recognize the limits of natural analogs as noted in the various comments. We consider natural analogs as one of several lines-of-reasoning behind the safety case. They provide some proof-of-principle that circumstances exist in which long-term containment can be achieved, and also information about processes or properties that are important. The analogs that demonstrate containment are of most interest because we want to understand the features that contribute to stability; however analogs that do not demonstrate containment can also be useful for understanding processes.

The Cigar Lake and Oklo continue to be very useful analogs, but others would also be brought forward such as:

- Nfld. Ferryland site bronze/iron artifacts - stability of copper and iron under reducing conditions for hundreds of years (McMurry et al. 2001);

- UK Devonian copper plates - stability of copper under reducing conditions for hundreds of millions of years (Milodowsky et al. 2000);

- deep water salinity and composition at the site as an indication of the age of the water and its history;

- fracture infill minerals at the site as an indication of the history of the site, such as depth of penetration of oxygenated waters (McMurry and Ejeckam 2002).

The current design does not use titanium, so natural analogs for titanium are not required.

References:

McMurry, J., B.M. Ikeda, M.J. Quinn, S. Stroes-Gascoyne, C.J. Hamon and P. Vilks. 2001. Metallic copper and iron artifacts in a corrosive depositional environment: The colony of Avalon archaeological analogue in Ferryland, Newfoundland. OPG Report 06819-REP-01200-10070-R00.

McMurry, J. and R.B. Ejeckam. 2002. Paleohydrogeological study of fracture mineralogy in the Whiteshell Research Area. OPG Report 06819-REP-01200-10082-R00.

Milodowski, A., M.T. Styles and V.L. Hards. 2000. A natural analogue for copper waste canisters: The copper-uranium mineralised concretions in the Permian mudrocks of south Devon, United Kingdom. SKB Technical Report TR-00-11.
7.03.01.04 Safety Assessment - Postclosure - Methodology - Coupled Processes

PARTICIPANT COMMENTS

Atomic Energy Control Board

AECL does not adequately consider the impacts of a number of coupled thermal-hydrologicalmechanical processes on the long-term integrity of the waste exclusion zone and safety.... AECL's reference design includes a 46.5 m waste exclusion zone of low permeability, competent rock between the wastes and a major fracture zone. This distance was determined without consideration of coupled T-H-M processes. AECB scoping calculations indicate that for some severe combinations of site conditions and rock mass properties, a larger waste exclusion zone could be required to provide an allowance for damage to a portion of the rock mass due to coupled T-H-M processes. [Comment 647, Source Document gov002, Page 60, Section C.4.1]

Campaign for Nuclear Phaseout

the EIS relies on linear models and fails to examine models which examine the effect of two or more processes. [Comment 1796, Source Document pub027, Page 25, Section III.E]

Mouvement Vert - Mauricie

AECL does not discuss the coupling effects, which could have a major impact on the stability of the vault.... The MVM would like the proponent to describe the effects of the various couplings in the proposed concept, or in a reference scenario. This discussion should take into account all of the possibilities of the significant coupling effects and their impact on the various components of the concept, notably the copper or titanium shell, the bentonite layer and the rock formation. [Comment 1489, Source Document pub024, Page 26, Section 2.4.3]

Northwatch

the EIS does not address the coupling of various processes, such as glaciation and its affect on groundwater; no examination of a combined effect of two or more processes is included [Comment 1383, Source Document pub046, Page 16, Section d]

Northwatch and Saskatchewan Environmental Society (Richardson)

the development of validated coupled models is essential before final safety assessments for candidate sites can be performed. [Comment 1599, Source Document ph2tec037, Page 14, Section 4.2]

Saskatchewan Environmental Society (Shettel)

Larger scale coupled hydrogeochemical models are needed to determine if electrochemical reactions between the different metals (copper and zircaloy) and nuclear fuel within the canister affect one another.... Empirical experimental results are necessary to confirm the theoretical combination of individual experimental models.... there may be other sources of metals outside the containers to consider for electrochemical reactions; these may include other unbreached canisters, rock bolts, steel mesh, and other materials not pulled after emplacement, such as rails, and mechanical and electrical items. Over the long time frames envisaged for permanent geologic disposal of nuclear waste, one must consider the possibility of electrochemical cells being set up within and even outside of the copper canisters. The consequences of electrochemical cells may be earlier than predicted failure of the copper containers with an earlier release of radionuclides. [Comment 1686, Source Document ph2tec038, Page 2]

In general, while individual hydrogeological and geochemical models may appear to yield confident results for approval of a conceptual design; if the individual models are coupled to consider possible interactions, different results may be obtained. Nature behaves as a system and therefore a total systems approach should be considered when modeling. [Comment 1687, Source Document ph2tec038, Page 3]

OPG RESPONSE

There has been a significant improvement in the availability and use of coupled and/or detailed models since the EIS. For example:

- the AECL MOTIF 6.3 code with coupled T-H-M is being tested and applied in the international DECOVALEX study to address topics such as effects of glaciation and of scale-dependence (e.g, Chan et al 1995);

- the U. Cardiff COMPASS code with coupled T-H-M is being tested and applied to the desaturation/resaturation behavior of the clay buffer/backfill (e.g. Thomas et al. 2002);

- the OPG MPM code is providing a detailed assessment of UO2 dissolution and the factors that are important to this process (e.g. King and Kolar 2002);

- the U. Waterloo FRAC3DVS code is being used to simultaneously analyze groundwater flow (including salinity effects) and solute transport;

- the CCM model is being developed to explore detailed processes related to copper corrosion, including microbial activity.

For a specific site, we expect to apply these and other tools to explore the candidate repository from a variety of technical aspects.

References

Chan, T., K. Khair and E. Vuillod. 1995. Generic study of coupled T-H-M processes of nuclear waste repositories as near-field initial boundary value problems (BMT2). In O. Stephansson, L. Jing and C.-F. Tsang (Eds.), Coupled Thermo-Hydro-Mechanical Process of Fractured Media, Developments in Geotechnical Engineering, Vol. 79, Elsevier Science B.V. pp.281-309.

Thomas, H. et al. 2002. Comparison of physical measurements and a finite element numerical simulation of water uptake and distribution in the Isothermal Test. OPG Report 06819-REP-01300-10042 R00.

King, F. and M. Kolar. 2002. Validation of the Mixed-Potential Model for used fuel dissolution against experimental data. OPG Report 06819-REP-01200-10077 R00.

7.03.01.05 Safety Assessment - Postclosure - Methodology - Precision and Accuracy

PARTICIPANT COMMENTS

Atomic Energy Control Board

The postclosure assessment modelling uses data and coefficients with an unwarranted number of significant figures, implying much greater precision and accuracy than can be justified. [Comment 658, Source Document gov002, Page 68, Section C.7.4]

OPG RESPONSE

The comment seems to be related to some specific intermediate calculations. We believe that use of more significant digits in intermediate calculations should not be of concern, to the extent that they are naturally produced in the course of calculations (and fitting function coefficients often require more digits than the final result accuracy). However, we agree that the input data and conclusions should appropriately reflect the confidence in these values. For example, the EIS Postclosure Assessment report tends to quote number to one or at most two significant figures, which is the level at which we would generally expect to provide quantitative results in any future safety assessment.

7.03.01.06 Safety Assessment - Postclosure - Methodology - Source Term PARTICIPANT COMMENTS

Environment Canada

there were also several issues that were not adequately addressed ... the difference between source terms used in the biosphere model and the postclosure assessment (given that the resultant risk in some cases may approach AECB limits, and the inconsistency between the source terms raises a serious credibility issue). [Comment 871, Source Document gov003, Page 27, Section 2.13]

Northwatch (Willis)

there is a kind of circularity to AECL's conceptual framework; assuming that the barriers are as effective as possible, then a subset of radionuclides can be identified as contributing most to the total radiation dose after the wastes starts to enter the biosphere. The complex modelling of environmental transfer mechanism ... is strongly influenced by the choice of radionuclides to focus on. In turn the assumptions about barriers -- for example what materials should make up the backfill -- are influenced by the choice of radionuclides to be modelled. [Comment 1569, Source Document ph3pub096a, Page 11, Section 6]

OPG RESPONSE

Comment #1.

An artificial source term (geosphere to biosphere) was indeed used in the Biosphere report for the sensitivity analysis. However, this was ONLY for sensitivity analysis of the biosphere model. This should be fine. The main postclosure assessment results and their sensitivities, as described in Goodwin et al. (1994), were based on the biosphere with the reference source term reflecting the full vault-geosphere-biosphere system model.

Comment #2.

The actual screening process assumed that most barriers were NOT effective. This is documented in Goodwin and Mehtal (1994), which might not have been available as part of the reference EIS documents. Furthermore, the engineering design was NOT particularly influenced by the specific radionuclides, but rather by more general criteria (e.g., the desirability of reducing conditions, the desirability of a diffusive-limited buffer region). However, we agree that it is desirable to check the conclusions from any screening analyses. One method that we have used, and will continue to use, for this check is comparison with the important contaminants that have been identified by other national waste management organizations, which reflect a variety of different vault models and reviews. Also, we have developed a radionuclide screening model that allows for a more substantive assessment of the implications of radionuclides (Goodwin et al. 2001). RSM 1.1 for example includes a database for all radionuclides with half-lives longer than 1 day.

References:

Goodwin and Mehta. 1994. Identification of contaminants of concern for the postclosure assessment of the concept for the disposal of Canada's nuclear fuel waste. AECL-10901, COT-93-265.

Goodwin, Gierszewski and Garisto. 2001. Radionuclide Screening Model (RSM) Version 1.1 - Theory. Ontario Power Generation Report 06819-REP-01200-10045-R0.

7.03.01.07 Safety Assessment - Postclosure - Methodology - Identification of Incorporated Scenarios

PARTICIPANT COMMENTS

Chemical Institute of Canada

AECL provides no indication of confidence or error bands for the performance of the Concept.... The availability of worked examples showing assumptions would help to respond to many of the Technical Issues raised and perhaps would have helped us to eliminate them as concerns. [Comment 1108, Source Document tec005, Page iii, Section es]

Health Canada

Modelling, using a range of values, would help a great deal in the assessment of the proposed storage technology. In addition, predicted exposure scenarios, using the model-derived contaminant levels, for both radioactive, and non-radioactive components would be valuable. For example, determination as to what concentrations of cadmium which might find its way into forage crops of caribou, which, in turn may be consumed by human receptors, might be one exposure scenario which could be examined. [Comment 997, Source Document ph2gov011, Page 11]

Northwatch (Willis)

While the simulations of radioactive releases (and doses to the public exhibit a wide range of possible outcomes, AECL averages them to produce a value which then is used to demonstrate' compliance with regulatory standards.... By use of averaging, the extreme' worst-case and best-case scenarios (which vary by as much as thirteen orders of magnitude) disappear into the middle greyness. [Comment 1570, Source Document ph3pub096a, Page 11, Section 7]

OECD/NEA Review Group

It is difficult for the reader to identify the sequence of events and processes which comprises the circumstances of any given scenario (although the code user can apparently do this). [Comment 1226, Source Document tec001, Page 13, Section 4.2]

The problem of completeness of scenarios is somewhat obscured (does a frequency distribution of results adequately represent the true probabilities of occurrence). [Comment 1227, Source Document tec001, Page 13, Section 4.2]

Scientific Review Group

It is unclear how specific scenarios of concern to the public could be identified in the dose distributions produced by SYVAC. For example, a scenario of a large urban development may be of interest, yet it is impossible to determine where estimated doses for this scenario would occur on the overall dose distribution curve. [Comment 438, Source Document tec004, Page 079, Section 6.6.2]

Performance assessment modelling results corresponding to extreme parameter values and to the variance of probabilistically generated results are not given. [Comment 449, Source Document tec004, Page 081, Section 6.6.3]

Although a large number of scenarios are embedded in the dose distributions presented, it is impossible to obtain an understanding of where particular scenarios of interest would emerge. For example, the portion of the dose to an aboriginal group eating a large amount of fish on the dose distribution curve will be of great interest to stakeholders, but this cannot be discerned from the results presented in either the EIS or the postclosure assessment document. [Comment 456, Source Document tec004, Page 084, Section 6.6.5]

it is unclear how specific scenarios of concern to the public (which would largely be worse-case) could be pulled out of the SYVAC output. [Comment 2156, Source Document tec004, Page 170, Section E-2.1.4]

OPG RESPONSE

It is expected that any future siting-related safety assessment will include evaluation of a number of 'what-if' scenarios, in addition to any probabilistic studies. The selection of these scenarios will depend in part on consultation with stakeholders.

It is expected that these will include explicit dose calculations to a wider range of human groups with different characteristics. This will make the impacts on these different groups clear.

Also, OPG is in the process of developing descriptions of the evolution of the repository for two scenarios - the design basis scenario and a defective container scenario. This work will clarify the sequence of events and processes which comprise these scenarios.

7.03.01.08 Safety Assessment - Postclosure - Methodology - Data Discontinuities

PARTICIPANT COMMENTS

Energy Probe (Rubin)

The EIS and its models must either use plausible data or the EIS must explain why not.... indicate where there are physically implausible discontinuities in [the] data because of the simple combination of algorithms. Preferably, AECL would do further research to reconcile the two algorithms at their boundaries. [Comment 2062, Source Document pub014r, Page 8]

OPG RESPONSE

The comment was specifically prompted by the use of two soil model algorithms, which result in a discontinuity in plant concentrations at the switch between the models (not a discontinuity in the data itself). These soil algorithms have been revised since the EIS; however the discontinuity still exists because one soil algorithm is a deliberately conservative model for use when the water table is close to the surface. Thus the discontinuous model does not cause an error in any particular result. Rather, as noted by AECL in this case, it can make the results seem more sensitive to a parameter than it really is.

There are no other discontinuities in the model of this type. However, there are other real physical discontinuities due to switches between distinct model states (e.g. use of lake or well water for drinking, different types of soils, oxidizing or reducing conditions in the geosphere, number of people in household).

7.03.02 Safety Assessment - Postclosure - Disposal System

7.03.02.01 Safety Assessment - Postclosure - Disposal System -Conceptualization

PARTICIPANT COMMENTS

Campaign for Nuclear Phaseout

The barrier system, as described in the EIS includes rocks, sediments and groundwater. They are described as part of the barrier, not as part of the natural environment. Presenting variables that are part of the natural environment as an incorporated part of the barrier is unusual and raises fundamental questions about the assumptions used in the design of the barrier system. [Comment 1802, Source Document pub027, Page 25, Section III.E]

Ecosystem Approach Group

the authors ... do not know where to place these microorganisms (which are part of the living world, and then should be in the biosphere, not in the geosphere). [Comment 2034, Source Document pub033, Page 06]

Northumberland Environmental Protection

AECL do supposedly succeed in constructing a generic model. It is, however, an exceedingly oversimpilfied model which blythly avoids every problem, instead of modelling the problems. The AECL method is to theoretically and hypothetically control the pathway in their modelled system such that the transport flow only remains within the engineered barriers, or a hypothetical (scarcely impermeable) Waste Exclusion Zone.... The AECL method is thus to avoid the whole issue of the prevailing uncertainty associated with rock characterization, and varieties of advective flow, which would hinder the construction of a generic model; and to ignore every bothersome problem, including degradation, crack propagation, alternative pathway. In other words the AECL vault-geosphere model is an invalid artifact. [Comment 1328, Source Document ph2pub010, Page 05]

Scientific Review Group

The separate models created for each barrier disregard the biological inter-connection, and thus implicitly minimize it. [Comment 402, Source Document tec004, Page 065, Section 6.4.2]

The essentially continuous network of microbiological activity from deep within the geosphere to the surface is ignored.... the definition of the biosphere shows the AECL approach ... to be one of considering biological elements to be passive factors in the transport of radionuclides. [Comment 254, Source Document tec004, Page 227, Section H-2.1]

the definition of the biosphere ... effectively excludes from consideration the subsurface biosphere and microorganisms which are commonly considered as a group of living organisms distinctly different from both plants and animals (including humans). The SRG distinguishes two major components of the biosphere, the surface biosphere and the subsurface biosphere ... Recent evidence is beginning to support the probability that there would be a part of the subsurface biosphere resident in (intrinsic) or contaminating (extrinsic) the geologic domain within which the disposal vault is emplaced [Comment 301, Source Document tec004, Page 241, Section I-1.1]

There is, for all discharge points from the geosphere to the surface biosphere, a probability of considerable biological activity which should be included in the disposal concept assessment. [Comment 303, Source Document tec004, Page 242, Section I-2.1]

There exists a growing body of evidence which indicates that there are at least two major components of the biosphere within a plutonic rock mass: microorganisms within fractures and larger conductive porous structures and metabolically active; and microorganisms within the finer pores of the rock in a state of suspended animation (metabolically passive). These microorganisms are of interest in the conceptualization of the modelling process for a variety of functional reasons including: the ability to infest the vault causing a variety of biofouling events (eg, corrosion, gas generation, clogging); the accumulation and transport of chemicals including contaminants; and the formation of a network between the vault and the surface biosphere using the groundwater as the conductive channel. [Comment 304, Source Document tec004, Page 242, Section I-2.2]

Since the role of the biosphere is ignored fundamentally in the geosphere, and the modelling process within the geosphere concentrates on physical and chemical parameters such as the hydrologic driving forces, the conceptual modelling process is incomplete and therefore subject to an undefinable range of errors. Clearly, in the modelling process, the clinical separation of the biosphere from the geosphere becomes unacceptable and any data and predictions so generated may become subject to errors. [Comment 305, Source Document tec004, Page 242, Section I-2.2]

OPG RESPONSE

Comment #1. The deep geologic disposal concept explicitly uses the geosphere as a means to improve the isolation of the used fuel from the surface biosphere. Furthermore, these components of the natural environment must be incorporated into the system models in order to see the behavior of contaminants in these components, whether they are act as a barrier or as a receptor.

Comments #2, #4 - #9 These comments relate to the degree of treatment of the microbial population within the EIS assessment. There has been much more work on the microbial population in the repository and its effects since the EIS was issued. The reader is referred to the discussion on this point under Comment Category 4.02.06 and elsewhere.

Comment #3. The approach does involve simplifications. Postclosure models compensate for this in part through (1) use of conservative models or data, (2) use of uncertainty ranges on parameters, and (3) validation of the models. The reviewers note a particular concern over barrier effectiveness; it is our intent to model the "what-if" effect of barrier failure more explicitly in future safety assessments.

7.03.02.02 Safety Assessment - Postclosure - Disposal System - SYVAC3-CC3

7.03.02.02.01 Safety Assessment - Postclosure - Disposal System - SYVAC3-CC3 - General

PARTICIPANT COMMENTS

Campaign for Nuclear Phaseout

The EIS inadequately describes the modelling procedures used to evaluate long term system interactions. What variables were included in the development of long-term models? What limitations were identified in these models as a result of parameter and data uncertainty? What criteria identified in Section 6.52 of the Final Guidelines were employed in the evaluation of long term responses of the systems and scenarios modelled? [Comment 1811, Source Document pub027, Page 28, Section III.F]

Northwatch

the EIS should discuss how AECL looked at non-linear models, eg. the chaos theory, and the reasons for relying on linear models only [Comment 1384, Source Document pub046, Page 16, Section d]

Scientific Review Group

The system model consists of a linear, largely uni-directional linkage between vault, geosphere and biosphere models with feedback only through a few "switches". [Comment 199, Source Document tec004, Page 191, Section E-5]

OPG RESPONSE

The overall models were described in the EIS and its subsidiary documents and references. The link to the panel guidelines was not transparent, although the intent was to cover the listed topics from the Final Guidelines. In any future safety assessment, we expect that there would be more explicit treatment of a number of the points noted, including long-term changes in the biosphere (eg glaciation) as well as of the processes and of the model uncertainties.

The system model was generally consistent with the models developed by other waste management organizations around the world at that time. The link between the vault to biosphere was generally unidirectional, since this reflected the processes that were important for radionuclides to have impacts on humans. However, important couplings in the reverse direction were also included in the models, notably the impact of well demand on geosphere flows (with the well demand based on biosphere considerations), and the impact on vault water flow due to the adjacent geosphere groundwater flow.

Specific phenomena are treated linearly or non-linearly as is described in the model reports. These system models continue to be improved and tested.

7.03.02.02.02 Safety Assessment - Postclosure - Disposal System - SYVAC3-CC3 - Limitations on Models

PARTICIPANT COMMENTS

OECD/NEA Review Group

The linking of research codes and SYVAC modules is not straightforward and the capability of SYVAC to incorporate directly the research codes is limited due to the use of convolution integrals. [Comment 1228, Source Document tec001, Page 13, Section 4.2]

Scientific Review Group

perceived requirements and computational limitations of the SYVAC code ... appear to have unduly con-strained the development of the underlying conceptual models and the acquisition and use of data from plutonic rock in the Canadian Shield. [Comment 322, Source Document tec004, Page 011, Section ES]

the development of BIOTRAC may have been constrained in part by computational limitations ... AECL should have continually re-examined choices that were made at an earlier time on the basis of the capabilities of computing equipment available at that time. [Comment 429, Source Document tec004, Page 074, Section 6.5.4]

The scenario selection process appears to have been impaired from an early stage by perceived requirements and computational limitations arising from the use of SYVAC. [Comment 441, Source Document tec004, Page 079, Section 6.6.2]

The size and nature of the computing equipment played a significant role in limiting the risk characterization by limiting the number of simulations. [Comment 196, Source Document tec004, Page 190, Section E-4]

Many restrictive assumptions are introduced to compensate for limitations of computer hardware and software... With more state-of-the-art software and computing technology, it should be possible to do away with many of the restrictive assumptions. [Comment 222, Source Document tec004, Page 204, Section F-2.1.6]

The SRG's review of the new information has reinforced its conviction that AECL's choice of, and continuing commitment to, a probabilistic risk analysis and the SYVAC technology has adversely influenced the orientation and emphasis of its research into the long-term safety of the disposal concept.... the basic task of characterizing, documenting, and assessing the fundamental implications of the pertinent attributes of the natural barriers, particularly the geosphere barrier, and of developing appropriate conceptual models, has been overshadowed by the task of implementing a computer-based probabilistic risk analysis with SYVAC. [Comment 530, Source Document tec004a, Page 14, Section 3]

Without the artificial and unnecessary constraint of the SYVAC framework, a three-dimensional vault model that is both mass conservative and consistent with a three-dimensional geosphere model could have been developed. [Comment 539, Source Document tec004a, Page 17, Section 3]

The new information provided by AECL reinforces the conviction of the SRG that AECL's performance assessment methodology has been driven by the requirements of SYVAC ... with parameter values selected from probability distribution functions that are of questionable significance.... this commitment to a probabilistic assessment has led to the use of a structurally flawed and incorrect geosphere model, and therefore, to results that are unreliable.... the SYVAC approach is unnecessary and should not have been used at the concept assessment stage. [Comment 540, Source Document tec004a, Page 18, Section 3]

OPG RESPONSE

We continue to believe that the use of multiple runs to provide probabilistic information is a useful part of a safety assessment, and suspect that its absence would be noted by reviewers. We also think that the approaches used in the EIS to solve the transport equations have some non-trivial advantages (e.g.. they are exact solutions within the range of validity of their approximations, and the algorithms are numerically robust).

We also think that it is important to distinguish between the SYVAC executive shell, and the CC3 and PR4 system models that were run under it. SYVAC provides a powerful capability for parameter sampling, probabilistic runs, and time series manipulations. As an executive shell code, it does not make any assumptions as to the specific system models. Future work can keep the useful SYVAC shell code, and improve those aspects of the CC3 or PR4 system models that were not satisfactory.

It is nonetheless recognized that computer resources have changed substantively since the EIS. Therefore, it is likely that any future safety assessment would include analyses using more than one code, and in particular including more detailed models. For example (depending on the site), the results of both discrete-fracture and continuum models of the geosphere might be presented. We are presently using and maintaining detailed finite-element models within the program, and are developing and testing alternative vault/geosphere models (e.g. see most recent annual reports).

7.03.02.02.03 Safety Assessment - Postclosure - Disposal System - SYVAC3-CC3 - Inflexibility

PARTICIPANT COMMENTS

Atomic Energy Control Board

The EIS does not demonstrate that the evaluation tools used in the postclosure assessment are appropriate for siting a disposal facility, as they do not appear to allow for defensible and timely decisions on the adequacy of a site.... Model sensitivity studies can be used for directing further work and for deriving design constraints only if the models being used are shown to produce accurate predictions, to be conservative or to be otherwise appropriate for making the predictions. None of these conditions have been met for the models used in the performance assessment presented in the EIS.... AECL has not demonstrated that new information can be readily incorporated into the assessment.... The systems model cannot be easily modified to account for anything other than variations in the conditions, processes and mechanisms assumed in the submodels. [Comment 593, Source Document gov002, Page 38, Section B.4.3]

Joint Committee of the Canadian Academy of Engineering and the Royal Society of Canada

The SYVAC system that AECL has developed has been criticized by the SRG as being unreliable, relatively inflexible and lacking state-of-the-art capability. Undoubtedly continuing improvements in computer technology and software will enable SYVAC's modeling performance to be enhanced, while the Second Case Study provides evidence of flexibility in its application. Our position is closer to that of TAC which sees the SYVAC results providing useful indicators of a range of possible future consequences. [Comment 1188, Source Document ph3tec001, Page 5]

Scientific Review Group

The SYVAC3-CC3 program described in the EIS focuses on a single model which has a fixed structure with respect to the contaminant transport pathways. This is a shortcoming of the initial problem formulation (scenario analysis and conceptual model development). The lack of any attempt to explore alternative model structures or various transport pathways is a fundamental flaw in the postclosure performance assessment. [Comment 442, Source Document tec004, Page 080, Section 6.6.3]

The SYVAC3-CC3 code appears much too inflexible to allow an observational approach during subsequent siting exercises. This is especially true given the chronic inattention given to the link between real field data and model parameters and inputs (especially in the geosphere). [Comment 444, Source Document tec004, Page 080, Section 6.6.3]

reliance on SYVAC has inhibited the introduction or use of more modern and flexible software and up to date data and has, to a degree, undermined the effectiveness of the assessments. [Comment 478, Source Document tec004, Page 098, Section 8]

Optimization of the code and full conversion for execution on present-day supercomputers will be necessary to adequately support future siting studies. [Comment 136, Source Document tec004, Page 154, Section E-S]

The description of the inherent ability of SYVAC3-CC3 to account for hundreds of different scenarios is difficult to accept. In AECL's view, SYVAC is flexible enough to accommodate alternative scenarios via changes in model parameters, initial and boundary conditions, source terms, etc. While this might be true in principle, SYVAC does not allow such changes without a major effort. [Comment 147, Source Document tec004, Page 170, Section E-2.1.4]

both the vault and geosphere models appear much too inflexible to accommodate the observational approach; and moreover, there has been a chronic (potentially fatal) failure to use up-to-date field data to refine model parameters/inputs in these models. Furthermore, AECL has failed to show how field observations will translate into improved model hypotheses and input data. [Comment 480, Source Document tec004, Page 175, Section E-2.1.5]

OPG RESPONSE

These comments reflect to some degree a basic trade-off in computer program selection for which there is no one correct soluton - adding more capability to the codes may allow more flexibility in responding to new information, but makes the codes harder to change (either to add additional models, or to revise the input files). Also, working in a quality-assured environment means that changes are made carefully, which again generally means a trade-off with speed of modification.

We also think that it is important to distinguish between the SYVAC executive shell, and the CC3 and PR4 system models that were run under it. SYVAC provides a powerful capability for parameter sampling, probabilistic runs, and time series manipulations. As an executive shell code, it does not make any assumptions as to the specific system models. Future work can keep the useful SYVAC shell code, and improve those aspects of the CC3 or PR4 system models that were not satisfactory.

The SYVAC3-CC3 followed a particular design emphasis that had a number of important advantages, including relatively fast execution, good QA and substantial numerical robustness, and a coupled vault-geosphere-biosphere. The flexibility of the model was demonstrated in part via the two case studies - SCS and EIS. And we have more recently used the model to simulate the SKB safety assessment study SR97. We still think that the design bases incorporated in the SYVAC3-CC3 models are useful for future safety assessments. Further validation and demonstration is planned.

However, we recognize that one code does not satisfy all demands, and intend that future safety assessments would be supported by several codes, which would range from simpler models that can be easily modified to test the importance of new processes, to more detailed models which can more faithfully represent the full site information.

7.03.02.02.04 Safety Assessment - Postclosure - Disposal System - SYVAC3-CC3 - Conservatism

PARTICIPANT COMMENTS

Northwatch and Campaign for Nuclear Phaseout (Kreusch, Neumann, and Gruppe Ekologie)

It has to be shown for every conservative assumption that it has indeed a conservative effect on the overall results of the calculations (It should definetely lead to an overestimation of the dose-rate and not to an underestimation). Actual proof of the conservativity of many assumptions made in AECL (1996) is not given. [Comment 1575, Source Document ph2tec044, Page 05, Section 2.2]

Scientific Review Group

the overall degree of conservatism versus realism in the case study analysis is unknown and the philosophy of AECL towards conservatism is unclear. [Comment 450, Source Document tec004, Page 082, Section 6.6.3]

Many assumptions upon which the system model is based are nonconservative ... The experimental runs performed by Elzas (1995) using SYVAC3-CC3 indicated that several parameters that were supposed to be conservative were not. For example, the standard values of terrestrial catchment area, total annual precipitation, well demand scaling factor, soil depth above the water table, well aquifer thickness and water content of food were found to be not conservative. These parameters would have to be carefully re-examined before the model could be used for siting purposes. The SRG concludes that SYVAC3-CC3 is not inherently conservative. [Comment 167, Source Document tec004, Page 183, Section E-3.1]

The SRG considers unacceptable the use of conservative assumptions to compensate for weaknesses or uncertainties in model structure (R-Postclosure 1994: p.348). ... some of the assumptions taken to be conservative may actually be non-conservative. Furthermore, conservatism used indiscriminately at every level of a modelling exercise does not necessarily induce proportionally greater conservatism. It leads to an untraceable degree of conservatism and then to increased uncertainty. The submodels within the biosphere model have this characteristic. [Comment 176, Source Document tec004, Page 185, Section E-3.1]

The mixture of conservative and realistic assumptions in the models making up the SYVAC code produces output that is unknown in its relative conservatism or realism. [Comment 194, Source Document tec004, Page 190, Section E-4]

OPG RESPONSE

We believe that conservative models and/or data are used in a wide variety of safety assessments, where it is sufficient to demonstrate that a consequence is below (or above) some criterion rather than how far from the criterion. We disagree with a blanket criticism of the use of conservative assumptions.

However, we agree that it is desirable for the reference system model to be as realistic as practical, and not invoke conservatism widely. In this regard, the EIS models and data were often intended to be reasonable or average, and NOT conservative. With respect to Comment #3, Elzas' (1995) analysis noted that some input values were "not conservative", because another value could have been used that would yield higher dose rate estimates. This is correct - the standard values used were intended to be average - not conservative - values (e.g., water content of food is clearly stated as an average value in the Biosphere report, p.256).

The general issues with using conservatism may be summarized as follows:

- The real margin to the criterion is not usually knowable.
- It is not always clear or proven that a given conservative assumption, model or data is indeed

conservative.

- The choice of data can make a "conservative" model produce non-conservative results.

We would propose to address these general concerns through the following approaches:

1. Provide more information on the degree of conservatism through further testing. As an example, summaries of the verification and validation status of the SYVAC3-PR4 and MOTIF 3.2 codes are provided in Garisto and Gierszewski (2001) and Chan et al. (2000), respectively. And the SYVAC3-CC4 (upgrade of PR4) has been tested against the Swedish SR-97 case study (Garisto et al 2001).

2. Further review of the models and data. An actual site licensing process will include opportunity for review of the system model and data, so that any inadvertent use of non-conservative models or data can be identified.

3. Use a range of models. These will span the range from detailed models of particular processes, to simpler models of the entire system, providing some cross-check on the importance of particular model assumptions.

4. Model and data reports should identify where they are intended to be conservative.

References

T. Chan, N. Scheier and F. Stanchell. 2000. MOTIF Version 3.2 Verification and validation report. Prepared by Atomic Energy of Canada Limited. Ontario Power Generation, Nuclear Waste Management Division report 06819-REP-01200-10026 R0.

F. Garisto and P. Gierszewski. 2001. Summary of verification and validation studies for SYVAC3-PR4 and its submodels. Ontario Power Generation, Nuclear Waste Management Division report 06819-REP-01200-10043 R0.

F. Garisto, P. Gierszewski, B. Goodwin, A. D'Andrea and M. Da Silva. Simulations of the SR97 safety assessment case using the NUCTRAN, RSM, DSM and PR4 codes. Ontario Power Generation, Nuclear Waste Management Division report 06819-REP-01200-10057-R0.

7.03.02.02.05 Safety Assessment - Postclosure - Disposal System - SYVAC3-CC3 - Vault-Geosphere Interface

PARTICIPANT COMMENTS

Natural Resources Canada

the ratio of drift area to total area of the vault array should be further reduced. This would reflect the actual effective area for flow entering the vault, considering that the fraction of the drift area occupied by buffer-filled emplacement boreholes is impermeable. Because of this, equation 6.28 in its present form probably underestimates specific discharge in the backfill by a factor of at least 2. [Comment 736, Source Document ph2gov001, Page geo7]

Section 6.2 (pages 79-83) describes the interface of the vault model with the geosphere model. Equations (6.4), (6.7), (6.12) and (6.13) (pages 82-3) give the radial and axial components of groundwater Darcy velocity in the EDZ and backfill, to be used in vault model calculations. However, the "equivalent resistor model" (for resistors in parallel ?) used to develop (6.4) is not appropriate for a radial system consisting of buffer, backfill and EDZ arranged in concentric layers... Indeed, the conceptual model for groundwater flow around the vault is unclear (see last paragraph, page 87) and the physical basis for the above equations is not adequately justified despite the checks documented in section 6.4.1 (page 92). [Comment 822, Source Document ph2gov015, Page 05]

OPG RESPONSE

Comment #1:

For the nominal EIS reference design (EIS Engineering, p.118), the buffer-filled boreholes are about 1.3 m diameter, with 2.1 center-to-center spacing in a 7.5 m wide tunnel. The ratio of buffer to total drift area in the vertical direction is 25%. Therefore, any correction due to the impermeable buffer should be much less than a factor of 2. Furthermore, if the backfill has higher permeability than the buffer, then it seems plausible that the groundwater flow would tend to flow around the buffer and fill in the "shaded" portion of the backfill, leading to a flow mass balance similar to Eqn.6.28. Overall, we conclude that any correction for the buffer is likely not a significant factor.

Comment #2:

The groundwater transport model around the vault-geosphere interface is clearly an approximation. However, it should be noted that the geosphere model takes an integrated flow from an entire vault sector as input into a single geosphere node, and so fine resolution of the vault-geosphere interface flows would not necessarily have produced more accurate results. The purpose of the verification tests documented in Section 6.4.1 was intended to confirm that the level of approximation was sufficient. Nonetheless, recognizing the concerns identified in these and similar comments, there is an ongoing work program to look at alternative models that can treat the vault and adjacent geosphere in better detail, and to carry out a more substantive testing of the models.

7.03.02.02.06 Safety Assessment - Postclosure - Disposal System - SYVAC3-CC3 - Geosphere-Biosphere Interface

PARTICIPANT COMMENTS

Natural Resources Canada

Section 6.7 describes the calculation of heads for the sediment and overburden nodes of the GEONET model. The proposed method (p. 221, para. 4) seems to preclude lateral flow between nodes in these high permeability layers. This is quite unrealistic since groundwater emerging from fractures zones at the bedrock surface is likely to flow horizontally rather than vertically through the overlying sediments towards the nearest surface discharge area. [Comment 737, Source Document ph2gov001, Page geo7]

it is not clear why the Biosphere model needs to be so strongly coupled to the Geosphere model or why obscure processes deep in the subsurface need to be modelled explicitly within the same SYVAC simulation. A simple input to the Biosphere model of "concentration versus time" curves would appear to be all that is needed. [Comment 824, Source Document ph2gov015, Page 07]

Scientific Review Group

the special definition of the geosphere-biosphere interface appears to lead to illogical interpretations in wetlands, where the water table is at the surface but which may be underlain by thick deposits of active organic material; in areas of deep fluvio-glacial deposits, common on the Canadian Shield, which may have several perched water tables; or areas where surface streams run over extensive outcrop. [Comment 255, Source Document tec004, Page 227, Section H-2.1]

OPG RESPONSE

n the particular case considered for this EIS study, it was judged that the flow was essentially vertical to the discharge points based on MOTIF modelling, and this is how the model was arranged. However, GEONET is capable of handling lateral flow connecting nodes; saturated layers of organic materials; or layers of permeable and impermeable materials; or a variety of saturated flow systems containing advection and diffusion elements.

If other unique features (e.g. perched water tables) of a particular repository site are important, then they should be appropriately modelled in any future assessment.

The geosphere and biosphere need to be strongly coupled because of the effect of well demand on the groundwater flows. The well demand itself is defined by the biosphere model. In general, the coupling of the vault-geosphere-biosphere was a specific feature of the SYVAC3-CC3 model that we believe provided useful information.

With respect to "obscure processes deep in the subsurface", it should be noted that this was one of the first studies anywhere with this level of detail, and was also conceptual rather than site-specific, so identifying which processes were important was an output of the study.

7.03.02.02.07 Safety Assessment - Postclosure - Disposal System - SYVAC3-CC3 - Modelling Detail

PARTICIPANT COMMENTS

Atomic Energy Control Board

There are inconsistencies in the level of detail and complexity in the CC3 simulation models.... The simulation of mass transport mechanisms in the geosphere and biosphere is more complex than in the vault. [Comment 582, Source Document gov002, Page 31, Section B.2.4]

Scientific Review Group

The vault and geosphere components of SYVAC3-CC3 were grossly oversimplified at an early stage of development of the models ... If the vault and the geosphere are so critical to system performance, it would have been preferable to model them in as much detail as is deemed scientifically feasible, and if necessary, to have done so at the expense of other system model components. [Comment 446, Source Document tec004, Page 080, Section 6.6.3]

OPG RESPONSE

This is being addressed in two ways:

1. Improvement of the models in the reference system model to a more consistent intermediate level of complexity. One change incorporated for the Second Case Study was the adoption of a somewhat more detailed vault model called INROC. Another change recently included is a simplified soil transport model.

2. Development (or acquisition) and use of models with both simpler (e.g. RSM) and more detailed (e.g. MOTIF, FRAC3DVS) capabilities.

7.03.02.02.08 Safety Assessment - Postclosure - Disposal System - SYVAC3-CC3 - Inappropriate Parameters

PARTICIPANT COMMENTS

Atomic Energy Control Board

Of the 12 "important" parameters in the median-value simulation identified in table 6-2 (Postclosure PRD, p. 167) and in Table 6-3 (Postclosure PRD, p. 169), 9 relate to the source term and transport of 129I and 14C, one is derived characteristic (tortuosity) of the assumed waste exclusion zone, and the other two are unmeasurable empirical scaling or correlation factors. The 8 important parameters in the probabilistic simulations identified in Section 6.5.5.2 (Postclosure PRD, Table 6-13 and p. 216) include the derived characteristic of the assumed waste exclusion zone (tortuosity), the two empirical scaling or correlation parameters identified in the median-value simulation and a switch controlling the occurrence of mutually exclusive exposure scenarios.... The reliance of the predictions of system performance on empirical and unmeasurable parameters is deemed to be inappropriate. [Comment 587, Source Document gov002, Page 34, Section B.3.3]

OPG RESPONSE

One of the purposes of sensitivity analyses is to provide a test of the "reasonableness" of the models. Most of the important parameters identified in the EIS Postclosure report - and in the SCS Postclosure reports (Goodwin et al. 1996, p.61) - are in fact measurable parameters and the sensitivity of the conclusions to these parameters is reasonable.

The specific empirical parameters found to be important in the EIS study (anion correlation parameter and velocity scaling factor) were not used in the Second Case Study, nor are they planned to be used in future assessments.

References:

B. Goodwin et al. 1996. The disposal of Canada's nuclear fuel waste: A study of postclosure safety of in-room emplacement of used CANDU fuel in copper containers in permeable plutonic rock, Volume 5: Radiological assessment. AECL-11494-5, COG-95-552-5.

7.03.02.02.09 Safety Assessment - Postclosure - Disposal System - SYVAC3-CC3 - Ease of Review

PARTICIPANT COMMENTS

Atomic Energy Control Board

The coding of SYVAC3-CC3 has become unnecessarily complex and unwieldy, and as a result auditing the calculations is onerous. [Comment 584, Source Document gov002, Page 32, Section B.2.4]

A presentation of the contaminant concentration at the lower boundary of the buffer as a function of time would make it easier to assess the calculations of the vault model. [Comment 597, Source Document gov002, Page 41, Section C.1.1(iii)]

Canadian Coalition for Ecology, Ethics and Religion

step-by-step computational schemes must be provided which can be followed with relative ease by external technical experts so that they can carry out independent key calculations and verify assumptions [Comment 1863, Source Document ph3pub160, Page 4]

Canadian Coalition for Nuclear Responsibility (Regroupement pour la surveillance du nucléaire)

provide a map of all the computerized models that play a role in the post-closure assessment. The map should indicate how the models are interconnected. [Comment 1890, Source Document pub049, Page 33]

Chemical Institute of Canada

AECL does not provide a step-by-step computation scheme which can be followed with relative ease by external technical experts, to carry out independently key calculations and verify assumptions, at least on an order-of-magnitude scale. [Comment 1109, Source Document tec005, Page 03, Section I.1.1]

The very impressive body of data and simulation work demonstrated in the AECL reports would be much more tractable, if systematic and coherent calculation paths, leading to the results presented in the key graphs had been shown in sufficient numerical detail, e.g. via sample calculations put in the Appendices. This material would largely dissipate the impression of certain graphs being "catapulted" into the text, and it would appreciably enhance the value and credibility of the report. [Comment 1124, Source Document tec005, Page 15, Section II.ii.D]

Environment Canada

Some important intermediate results generated in BIOTRAC and SYVAC3 are missing, therefore hindering a quantitative review of the calculations.... it is recommended that detailed documentation of the BIOTRAC and SYVAC3 codes be made available. [Comment 894, Source Document gov003, Page 36, Section 2.16]

Northumberland Environmental Protection (Fairlie)

key values in AECL analyses are not disclosed in the reports. As it is then impossible to check on the figures, the results are not reproducible. One serious omission is the biosphere dose factor, Sv/a per Bq/a, ie the dose to an average member of the critical group per unit rate of nuclide to biosphere. It is not possible to trace how the extremely small doses to the critical group are arrived at. Clearer calculations are presented in the CI-36 paper by Johnson et al (1995), but unfortunately it is still not possible to calculate the maximum discharges and discharge rates to biosphere (in becquerels) for key nuclides from the data presented, nor collective dose rates arising from them. [Comment 1344, Source Document ph2tec006, Page 04]

OPG RESPONSE

We believe that any computer program able to analyze the range of features likely to be seen in a deep geologic repository will inherently be a large computer program, and therefore not readily amenable to easy review.

Nonetheless, we are continuing to improve the clarity of the models, computer programs and results as follows:

1. Following a software quality assurance approach. The system model (SYVAC3-CC3, as developed by AECL for the EIS) and its current version (SYVAC3-CC4 as maintained by OPG) follow software quality assurance standards, which help make code review more tractable; e.g., use of standard module formats, use of code comments, complete variable definitions with units. The standard presently being followed by OPG for the maintenance and development of such safety assessment computer programs are described in (CSA 1999, NWMD 2000).

2. Preparing separate reports for the model theory, code design, code user manual, and code verification and validation testing of the main safety assessment system model. (In the EIS/SCS reports, much of this information was interspersed with the case studies).

3. Preparing alternative simpler models that should be able to reproduce the main features of the detailed model results. For example, the Radionuclide Screening Model (RSM) uses a simplification of the CC4 theory (Goodwin et al. 2000) but uses the robust SYVAC3-based numerical approach. Other simplified models prepared using, say MathCAD, may also be used to illustrate specifid results.

4. Providing nuclide fluxes at the vault-geosphere and geosphere-biosphere interface as useful intermediate information. This has in fact become standard practice in safety assessments since the EIS/SCS, e.g. SR97 (Lindgren and Lindstrom, 1999).

References:

CSA. 1999. Quality assurance of analytical, scientific, and design computer programs for nuclear power plants. Canadian Standards Association standard N286.7-99. Rexdale, Ontario.

Goodwin B. et al. 2001. Radionuclide Screening Model (RSM) version 1.1 - Theory. Ontario Power Generation, Nuclear Waste Management Division report 06819-REP-01200-10045 R0. Toronto, Ontario.

Lindgren M and F. Lindstrom. 1999. SR97 Radionuclide transport calculations. Svensk Karnbranslehantering AB (SKB) technical report TR-99-23. Stockholm, Sweden.

NWMD. 2000. Software. Ontario Power Generation, Nuclear Waste Management procedure, W-PROC-EN-0005 R0.

7.03.02.02.10 Safety Assessment - Postclosure - Disposal System - SYVAC3-CC3 - Comparison with UTAP

PARTICIPANT COMMENTS

Atomic Energy Control Board

Some of the validation tests for SYVAC are not relevant to deep geological disposal of nuclear fuel waste. For example, SYVAC3 was compared to the UTAP model as part of the validation activities for SYVAC3 (Postclosure PRD, Section B.4.2.1). However, UTAP is inappropriate for this purpose since it models the processes relevant to the shallow ground disposal of uranium mine tailings as opposed to the processes relevant to the deep geological disposal of nuclear fuel waste, which SYVAC attempts to model in this EIS. [Comment 665, Source Document gov002, Page 70, Section C.8.5]

OPG RESPONSE

There are limited opportunities for validation of the system models for used fuel disposal. Therefore, the approach is to use as many partial validations as practical. The overall confidence in the results should not depend on any one test of limited applicability, but on the results of a large set of tests that consider different aspects of the model.

For the specific example cited of uranium mine tailings, the solute transport processes occurring in shallow ground (relatively homogenous, porous conditions) are not necessarily those in fractured rock. However, the geosphere model should work under these shallow ground conditions, and so it builds confidence in the model to know that this is indeed the case. Furthermore, such tests could potentially be used to directly validate other parts of the system model, such as the geosphere-biosphere interface.

7.03.02.03 Safety Assessment - Postclosure - Disposal System - Chlorine-36 PARTICIPANT COMMENTS

Environment Canada

Other issues identified as being of concern were: ... the very brief treatment of chlorine-36 in the postclosure assessment, despite its importance [Comment 875, Source Document gov003, Page 27, Section 2.13]

OPG RESPONSE

This comment, from a 1995 Environment Canada report, was issued before the SCS results were available to reviewers. The SCS did consider CI-36 in much more detail, including the derivation of specific biosphere pathways. Its importance to humans and non-human biota are clearly acknowledged in the SCS reports (e.g. SCS Postclosure, Vol.5 Radiological Assessment, AECL-11494-5, 1996). See also Johnson et al., 1995, Radiological assessment of 36Cl in the disposal of used CANDU fuel, AECL-11213.

7.03.02.04 Safety Assessment - Postclosure - Disposal System - Technetium-99

PARTICIPANT COMMENTS

Atomic Energy Control Board

About 6% of the total inventory of 99Tc in the fuel is present in the instant release fraction (IRF).... Considering the uncertainty in the redox conditions in the vault following closure and the high solubility of Tc under oxidizing conditions, the EIS should have calculated an ADE for 99Tc assuming that it is dissolved and transported under oxidizing conditions, and thus not precipitated in the buffer and backfill. [Comment 605, Source Document gov002, Page 42, Section C.1.2(ii)]

OPG RESPONSE

The presence of reducing groundwater conditions at depth, and the availability of a large mass of rock mass to help return conditions to reducing after vault closure, is an important characteristic of the deep geological disposal concept that would be confirmed as part of the siting process. Evidence continues to build that conditions at vault depths in the Canadian Shield remain reducing, even under such perturbations as glaciation (e.g. Gascoyne 2000, Guimera et al. 1999). Within the vault itself, the presence of copper, iron (in failed container), and microbes and iron minerals in backfill should all contribute to development of anoxic conditions.

Therefore, the assumption of oxidizing conditions AND groundwater access to the canisters should be considered as very unlikely, and the reference case should be based on anaerobic conditions.

However, as has been noted in other responses in this database (e.g., 7.03.13.02), future safety assessments will likely consider several specific "what if" scenarios that reflect the interests of the main stakeholders. This oxidizing conditions case could be proposed as such a scenario.

References

M. Gascoyne. 2000. Hydrogeochemistry of the Whiteshell Research Area. OPG Report 06819-REP-01200-10033 R0.

J. Guimera, L. Duro, S. Jordana and J. Bruno. 1999. Effects of ice melting and redox front migration in fractured rocks of low permeability. SKB TR-99-19.

7.03.02.05 Safety Assessment - Postclosure - Disposal System - Radionuclide Speciation

PARTICIPANT COMMENTS

Canadian Coalition for Ecology, Ethics and Religion

In both the case presented in the EIS and that of in-room emplacement, assumptions are made with respect to the retardation of various nuclides in the ground water through chemical precipitation or sorption but the validity of this optimism is unknown. These claims are not supported by any discussion of the chemical species of these radionuclides and it is the chemical form which dictates if and how the radionuclide will move in the biosphere. For both solubility and potential to be retarded in the system, little information is provided on the chemical species and little consideration of the variability and complexity possible due to different forms. [Comment 1871, Source Document ph3pub160, Page 7]

OPG RESPONSE

Precipitation and sorption are dependent on the chemical conditions (e.g., Eh, pH, temperature, salinity) in the groundwater. In the EIS, the dependence of the solubilities of the elements U, Pu, Np, Th and Tc on the groundwater composition was explicitly taken into account (Johnson et al. 1994, Lemire and Garisto 1989). For all other elements, conservatively large solubility values were used in the assessment. Furthermore, the nuclides contributing the most to the calculated total doses (I-129, CI-36 and C-14) have large solubilities under potential vault conditions and have relatively simple aqueous chemistries. For example, both iodine and chlorine form stable univalent anions in water.

The absorption coefficients used in the assessment were derived from experiments carried out under the chemical conditions expected in the vault, geosphere or biosphere. Consequently, if the chemical conditions in the vault, geosphere and biosphere do not deviate greatly from the expected conditions, the measured absorption coefficients would already implicitly account for the chemical speciation of the elements in the various compartments. In addition, in the EIS, the probabilistic distributions assigned to the absorption coefficients are fairly wide and implicitly account for any effects due to changes in chemical speciation.

References

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7.03.02.06 Safety Assessment - Postclosure - Disposal System - Dispersivity PARTICIPANT COMMENTS

Scientific Review Group

Spatial variability means that transport paths cannot be predicted deterministically, yet these paths are frozen in the vault and geosphere model. To the extent that one ignores uncertainty in travel paths (as does CC3) one must compensate for this by building into the model enhanced dispersities (by orders of magnitude). This would greatly affect the diffusive transport predictions. [Comment 2159, Source Document tec004, Page 183, Section E-3.1]

OPG RESPONSE

The transport paths adopted in the EIS model were based on particle tracking of solutes under a 3-D model (MOTIF) that reflected a reasonable representation of the WRA model as was known at the time, including spatial variability.

However, the geosphere model (GEONET) used in the system code did treat uncertainty in an approximate manner, and the extent of this approximation was not well defended. As a minimum, we expect that a future safety assessment will consider more than one conceptual model of the site hydrogeology, so that there will be explicit consideration of factors as spatial variability in the properties of the geosphere. Furthermore, we are working towards a direct coupling between the site characterization geosphere model and the safety assessment model, so that the geosphere variability and uncertainties can be propogated directly into the safety assessment models. This is a longer term goal; current status is described in our annual technical reports (eg. Gierszewski et al. 2003).

References

Gierszewski, P. et al. 2003. Deep Geologic Repository Technology Program Annual Report 2002. OPG Report 06819-REP-01200-10100 R00. 7.03.03 Safety Assessment - Postclosure - Vault

7.03.03.01 Safety Assessment - Postclosure - Vault - Conceptualization PARTICIPANT COMMENTS

Atomic Energy Control Board

AECL's assumption that all contaminant releases from the buffer must enter the backfill is not conservative.... AECB scoping calculations indicate that a 1 m thick excavation damage zone with an apparent diffusion coefficient that is ten times greater than that used for the backfill would result in a significant percentage of released contaminants bypassing the backfill.... AECL has not adequately considered mechanisms by which contaminant releases from the buffer could bypass the backfill. Also, the consequences of bypassing the backfill have not been adequately evaluated. As such, AECL has not adequately justified the use of a one-dimensional vault model that forces all contaminant releases from the buffer to pass through the backfill. [Comment 564, Source Document gov002, Page 17, Section A.3.2]

The assumptions that the vault can be represented as a planar source and hence that radionuclide transport can be modelled using a one-dimensional transport model (Vault PRD, p. 162) is an oversimplification that has not been shown to be appropriate or conservative.... The Vault PRD (Figure 6-3 p. 169) clearly shows that radionuclides would diffuse radially through the annular buffer and into the surrounding rock pillar much faster than through the backfill. Once in the rock, the contaminants are vulnerable to capture by advective flow if fractures are present.... Considering the biases introduced into the predictions by the one-dimensional-transport-using-MTCs approach to simulating the vault, it is questionable whether the vault model is appropriate for estimating probable releases at any time, let alone up to 105 years (Postclosure PRD, p. 129). [Comment 578, Source Document gov002, Page 29, Section B.2.2(i)]

The structure of the Vault Submodel results in artificial retention and delay of the contaminants.... The implementation of the simplified 1-D transport model representing a series of planar layers results in underestimation of the vault release rates.... The comparison between the spherical and planar waste forms (Vault PRD pp. 167-168) is not convincing.... The one-dimensional "simplification", then, provides two to four times the retention capacity in the buffer than the reference design of the vault.... The backfill is an important barrier due to its high porosity and sorption capacity, and the effects on contaminant transport of cracks in the backfill are not assessed, neither theoretically nor experimentally. [Comment 594, Source Document gov002, Page 39, Section C.1.1(i)]

Applying the container failure function to the contaminants released from the waste matrix prior to their transport through the buffer is inappropriate (Postclosure PRD, p. 90).... Applying the container failure function to the releases from the waste matrix instead of from the buffer effectively dilutes the instant release inventory in one container into the void volume of all the containers. [Comment 596, Source Document gov002, Page 41, Section C.1.1(iii)]

Campaign for Nuclear Phaseout

In describing the parameters of the vault, a one dimensional model is used. Were non-linear models examined? If so, what was the rationale for their omission from the EIS? [Comment 1797, Source Document pub027, Page 25, Section III.E]

Hare, Driedger, Jennekens, Rogers, and Shemilt

Among the subjects of concern are ... the use of one-dimensional modelling of the transport of radioactive materials from the vault [Comment 1410, Source Document phpub150, Page 4]

Natural Resources Canada

a 1-D model is not conservative because it artificially constrains radionuclides to follow a straight path through the buffer and backfill rather than allowing them to seek the path of least resistance which is likely to be a lateral one, through the buffer and directly into the EDZ where convective transport may dominate. A more thorough discussion of the shortcomings of a 1-D model is warranted. [Comment 725, Source Document ph2gov001, Page vau5]

It is unclear whether or not the transport model described in section 6.4 considers the downward diffusion of radionuclides from the container to the buffer and the geosphere. [Comment 726, Source Document ph2gov001, Page vau6]

Northwatch

the EIS should discuss the integrity of the vault, and clearly set out AECL's reasons for relying on a one-dimensional model for validation of the vault integrity [Comment 1374, Source Document pub046, Page 15, Section d]

OECD/NEA Review Group

transport from the vault is calculated with a simple 1D model backed-up by 3-D model calculations. This is common practice in safety assessments of deep geological repositories, where more complex research models are used to provide data for simplified safety assessment models. More explicit justification of the adequacy and validity of the 1-D modelling would have been of value. [Comment 1206, Source Document tec001, Page 08, Section 3.1.4]

Scientific Review Group

the assumption that the barrier components (buffer, backfill, rock) always act sequentially, and that therefore contaminant transport through the vault components can be approximated by a onedimensional layered model, will be valid only if the buffer and backfill are perfectly placed everywhere and remain as placed for the entire period, allowing no shortcuts for contaminant migration, and furthermore that the direction of transport is always upward.... This assumption might be justified if the containers were enclosed fully by both buffer and backfill on all sides.... in the reference design ... there is no backfill between the buffer and the surrounding rock. If the direction of contaminant transport is not everywhere upward from the containers, some of the contaminants will move directly from the buffer into the surrounding rock, bypassing the backfill. Thus the assumption of sequential transport through the barrier components is clearly non-conservative. [Comment 360, Source Document tec004, Page 050, Section 6.2.3]

A further potentially non-conservative consequence of the 1D approximation of the vault model arises with respect to the radionuclide dissolution rate at the source. The rate of release depends not only on the solubility of the fuel waste but also on how rapidly mass is transported away from the source. The rate of mass transport depends on the concentration gradient, which differs between 1D and 3D sources due to the geometric configuration. As a result, mass will be transported away faster from a 3D source than a 1D source, allowing for faster mass release from a solubility-limited source (R-Vault 1994: p.168). The dissolution rate also depends on the source surface area; in the 1D vault model, the vault surface is used (R-Vault 1994: p.143). AECL has justified these approximations with the argument that over long time intervals, the difference between a 1D source and a 3D source becomes small (R-Vault 1994: p.168). This premise, however, is based on the assumption that mass transport will eventually be uniformly upward in the vault. If other transport scenarios were to apply (see above), this premise might be invalid. The approximation of a 3D source by a 1D source may therefore be non-conservative [Comment 362, Source Document tec004, Page 050, Section 6.2.3]

a major weakness of the AECL analysis is the one-dimensional approximation of the reference vault model, which disallows the investigation of possible scenarios where the backfill is imperfect, or where escaping radionuclides pass directly from the buffer into an excavation-damaged and imperfectly sealed rock and thence into a fracture zone connecting to the surface environment.... the assumption of one-dimensional transport in the vault may therefore be non-conservative, and the assumptions stemming from it, namely sequential diffusive transport in the vault components and negligible effect of the excavation-damaged zone, may likewise be non-conservative. An investigation of transport scenarios that are not constrained by the one-dimensional approximation of the reference vault would have been useful. [Comment 368, Source Document tec004, Page 051, Section 6.2.3]

The important role found to be played by the backfill in retarding contaminants is entirely an artifact of the one-dimensional vault model. Advection may play a much more important role in transport through the vault, and diffusion a much lesser role, than is allowed in CC3. The movement of all contaminants may thus be enhanced. Contaminants such as 99Tc and 238U, which are assumed to sorb strongly within the backfill, have a much lesser chance of sorbing within the rock webs due to greatly reduced clay content and surface area relative to the backfill. They would appear at the vault-geosphere interface much sooner. Placing a backfill in the path of each molecule is thus distinctly nonconservative. [Comment 180, Source Document tec004, Page 186, Section E-3.1]

The layered representation of the disposal vault which forms the basis for most of the modelling is flawed fundamentally because it does not allow for a direct lateral route of radionuclide migration from the buffer-rock borehole contact areas through the rock web between boreholes or emplacement rooms... the following are implied: (a) the buffer is in contact with backfill but generally not with the rock (though such contact is sometimes considered, as in Figure 6-6, p. 188); and therefore (b) radionuclides released from the container must generally penetrate the backfill before making contact with rock. The first implication (a) is contrary to the reference vault design ... according to which the area of contact between buffer and rock is much larger than the area of contact between buffer and backfill. The second implication (b) is likewise contrary to the reference vault design, according to which radionuclides released into the rock which surrounds the emplacement boreholes have a relatively small chance of ever entering into the backfill, since most of the repository area consists of rock.... Conservatism would dictate that the backfill be eliminated from the one-dimensional transport code for the case of in-borehole emplacement. [Comment 210, Source Document tec004, Page 197, Section F-2.1.1]

The Vault Model assumes that transport in the reference vault design is diffusion dominated However, this assumption has not been substantiated... Transport in the rock which surrounds the vault is not necessarily diffusion dominated ... Therefore, the geosphere calculations should not be cited to argue that transport in the backfill, and in the rock webs between the emplacement rooms, is purely diffusive

... The SRG concludes that AECL has not demonstrated adequately that a uniformly low hydraulic conductivity throughout the buffer backfill materials in the vault, which would support the assumption of diffusive transport, is possible to achieve in practice, or to maintain for the following reasons: - the materials are not pure clay but mixtures;

- there is no indication that the backfill material can be compacted to specifications, especially against the walls and roof of each room;

- there is no indication that gaps can be filled with material having the specified uniform low permeability; and

- there is no indication that the backfill can or will be tested in situ to ensure that it has in fact attained this uniform low permeability. [Comment 211, Source Document tec004, Page 197, Section F-2.1.2]

the new cylindrical vault model ... the fundamental requirement of mass conservation between the cylinders, and between the vault and the geosphere, cannot be satisfied. Furthermore, the structure of the vault model is inconsistent with that of the geosphere model (MOTIF), and it is not clear how the two models are linked in a physically meaningful way. For these reasons, the theoretical basis of the model has doubtful validity [Comment 538, Source Document tec004a, Page 17, Section 3]

It is acknowledged that vault conceptualization and optimization of vault design are important issues for geologic disposal.

The vault design selected for the EIS postclosure assessment case study was selected after several iterations. Detailed hydrogeologic modelling using the MOTIF finite element code (Goodwin et al. 1994, p. 144-148) had shown that placement of vault rooms above the fracture zone LD1 would have resulted in relatively rapid downward movement of contaminants released from failed containers. The contaminants would have by-passed the backfill, leading to larger predicted doses. Hence, for the EIS postclosure assessment case study the vault design was improved, in order to increase safety margins, by eliminating all vault rooms above the LD1 fracture zone and increasing the waste exclusion zone to about 50 meters. This optimization in vault design is reasonable. It is expected that, as was done in the recent SR97 safety assessment (SKB, 1999), hydrological modelling studies would be performed when selecting a vault design for a particular site.

MOTIF hydrogeologic studies for the vault design in the EIS postclosure assessment case study indicated that groundwater velocities in the surrounding low permeability rock were upward and small. Consequently, in the EIS case study, nuclides migration from the vault was preferentially in the upward direction. For this reason, it was deemed that a simple 1 dimensional sequential (fuel, buffer, backfill, geosphere) model would be appropriate for modelling contaminant transport in the EIS postclosure assessment case study. The 1-D model assumes that transport of nuclides is in the upward direction only.

The appropriateness of the 1-D model was evaluated by comparison with MOTIF calculations (Johnson et al. 1994, Figure 6-3, Garisto and LeNeveu 1991, Figure 2-10). Although the MOTIF calculations showed that, in the pure diffusion case, some nuclides move directly through the buffer to the rock below the disposal room, thus bypassing the backfill, the comparison showed that both the MOTIF and 1-D models calculated the same breakthrough time for I-129 to the overlying fracture zone. This is because the large storage capacity of the backfill still played a role in slowing upward migration of the diffusion front. 3-dimensional analyses were also carried out (Davison et al. 1994) to investigate the sensitivity of convective groundwater transport between the vault and biosphere to the hydrogeological properties of the near-field region within and surrounding the disposal vault. These studies showed that the existence of a 3 m thick EDZ, with permeability up to 100 times that of the undamaged rock, had no significant effect on convective contaminant transport from the vault, mainly as a result of the "hydraulic cage" effect.

For these reasons, AECL claimed that the 1-D vault model accurately represented the contaminant transport, at least for the particular EIS case study. Nevertheless, the test case did show that nuclides were able to by-pass the backfill. Investigation of what-if scenarios in which the backfill is by-passed would have been instructive and would have addressed many questions.

The use of simple 1-D models, backed-up by more complex 3-D model calculations is a common practice in safety assessments of deep geologic repositories (SKB, 1999). Although some assessment of the validity of the 1-dimensional transport model used in the EIS was made, because of the importance of the backfill and the possibility that it could be bypassed (e.g., by nuclide migration through the excavation damaged zone), we agree with the OECD/NEA Review Group (1995) and others that "more explicit justification of the adequacy and validity of the 1-D modelling would have been of value". In particular, further studies on the effect of the EDZ zone on nuclide migration should have been carried out. Subsequent to this review, the effect of the EDZ on I-129 transport from a repository was evaluated (Chan et al. 1999). It is expected that in any future assessment, the validity of using simplified transport models would be fully supported by detailed studies with 3-dimensional transport codes.

It is acknowledged that a 1-dimensional model may not be appropriate for all situations. In fact, in the SCS, an in-room emplacement vault design was used and a 3-dimensional boundary integral model

was used to model nuclide transport in the vault (Johnson et al. 1996). The deficiencies in the cylindrical vault model are acknowledged and work is currently in progress to develop additional tools for calculating nuclide transport through the vault.

Transport in the sealing materials (buffer and backfill) is assumed to be diffusion dominated. In fact, groundwater flow velocities are small in the backfill (about 1.0E-6 m/a) and are zero in the buffer. These assumptions are supported by experimental laboratory measurements which show that hydraulic conductivities would not exceed 1.0E-10 m/s in the backfill material and 1.0E-11 m/s in the buffer. Thus, diffusion would be the dominant transport mechanism in these sealing materials because the hydraulic conductivities are less than 1.0E-9 m/s throughout the materials (Mitchell 1976, 1991). Furthermore, it is expected that quality assurance procedures will be in place to ensure that the sealing materials used in the vault will meet the required specifications.

Because a solubility limited dissolution model was used to calculate UO2 dissolution rates in the EIS, the predicted dissolution rates depends on the dimensionality of the transport model (Garisto and Garisto 1988). However, it is expected that in the future, a kinetic fuel dissolution model would be used to predict the rate of UO2 dissolution, following the approach used in the Second Case Study (Johnson et al. 1996). In this case the dimensionality of the transport model would not affect the rate of UO2 dissolution.

Finally, the procedure used to calculate the releases from all failed containers seems correct (Johnson et al. 1994, p. 149-150). In the model, only nuclide releases per container are ever calculated. The formula used to calculate releases from all failed containers (Johnson et al. 1994, Equation 5.19) essentially sums up the releases from each failed containers, taking into account the time of container failure. In this approach, there is no mechanism by which the instant release inventories from one container can be diluted into the void volumes of all containers.

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7.03.03.02 Safety Assessment - Postclosure - Vault - Container PARTICIPANT COMMENTS

Natural Resources Canada

In the case of titanium containers, the approach which has been taken is clearly inconsistent with the concept of a corrosion-resistant material which would be expected to resist the initiation of crevice corrosion.... life predictions have been made on the basis of measured propagation rates ... Unfortunately, the original model proposed in the PRD and based on weight-change measurements is flawed. The subsequent re-evaluation of the model using depth-of-attack data reported in (AECL-11255/COG-95-018) is open to alternate interpretations based on more conservative assumptions. [Comment 793, Source Document ph2gov001a, Page 06, Section 2.1]

OECD/NEA Review Group

the corrosion lifetime of the container may indeed be much longer than 10,000 years, as it is suggested by AECL, but it would need to be properly justified{2}, whether for Ti or for Cu
residual uncertainties in lifetime are adequately convoluted in the early container failure fraction. The latter is related to the potential presence of manufacturing defects and current estimates are based on statistics from existing manufacturing processes. A better figure can be obtained only when the whole fabrication sequence, including welding and other hot cell operations, is demonstrated. [Comment 1201, Source Document tec001, Page 07, Section 3.1.2]

Saskatchewan Environmental Society

Although the copper container system appears to have improved the security of the containment, we do not see any assurance that wastes will be isolated for the time period indicated. Estimates are being suggested, but these are based on hypothetical sites and hypothetical container leakage rates, and cannot provide the needed assurance. [Comment 1690, Source Document ph2tec039, Page 2]

OPG RESPONSE

The current reference disposal container is a copper shelled container with a carbon steel inner vessel (Maak 1999; Poon et al. 2001). There is substantial theoretical (e.g., thermodynamic data) and experimental evidence to indicate that copper corrodes very slowly under reducing conditions (e.g., natural analogue described by Milodowski et al. 2000). Therefore, it is expected that such copper containers will last at least 100,000 years, and likely more than 1 million years. Work is continuing to ensure that there are no copper corrosion mechanisms that would significantly reduce the lifetime of the copper corrosion containers.

As noted, the number of expected manufacturing defects in the copper containers can only be estimated at this time based on analogy with other welded containers (Doubt 1984, Maak et al. 2001). Further container specific information will be available after the whole container fabrication sequence has been demonstrated. Work on relevant container fabrication is presently underway as part of the Swedish and Finnish programs.

References

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7.03.03.03 Safety Assessment - Postclosure - Vault - Parameters

7.03.03.03.01 Safety Assessment - Postclosure - Vault - Parameters - Instant Release Fraction

PARTICIPANT COMMENTS

Atomic Energy Control Board

Fourteen radionuclides are identified as having a significant Instant Release Fraction (IRF) comprising their gap and grain boundary inventories (Vault PRD, p. 128). There are some inconsistencies in the reporting of the IRF elsewhere for some of these, and the IRF of most of these isotopes are not included in Table E-1 (Vault PRD), which lists the vault model inputs.... Because 137Cs has about the same half-life as 90Sr and the same chemical interaction as 135Cs, it should not be excluded on the basis of half-life or retardation. [Comment 604, Source Document gov002, Page 42, Section C.1.2(ii)]

The derivation of the instant release source term is not supported adequately, and there are inconsistencies and errors in the equations presented in the PRD and the references cited. [Comment 606, Source Document gov002, Page 42, Section C.1.2(iii)]

Northumberland Environmental Protection (Fairlie)

There is paucity of information on immediate release fractions as discussed by the IAEA (IAEA, 1991), and little consensus on how this matter is treated by other countries in their assessments (Neall et al, 1994) of their spent fuel disposal concepts.... The EIS's treatment of Tc-99, Cs-137 and C-14 release fractions were criticised by the SRG and the AECB: these points need to be considered and the matter examined afresh. [Comment 1343, Source Document ph2tec006, Page 04]

Scientific Review Group

The distribution of the various radionuclides within the fuel waste matrix, at the grain boundaries, and at the fuel waste-sheath gap (R-Vault 1994: p.128; Johnson and Shoesmith 1988) is supported qualitatively by experimental information; however, in some instances, the quantitative analysis of these data does not appear to be justified. Extrapolation of experimental information to generate the distribution functions for the instant release fraction of radionuclides (EIS 1994: p.26; R-Vault 1994: p.132) has been, in part, more intuitive than concrete particularly in the case of selenium, tin, technetium, and carbon and perhaps of chlorine. [Comment 349, Source Document tec004, Page 045, Section 6.2.2]

the reliability and accuracy of the instant release fraction values are of paramount importance. The SRG is concerned about the lack of rigour with which this matter has been treated in studies to date. The values of the instance release fraction are based on uncertain experimental data and are described in the models by probability density functions that are in some cases assigned arbitrarily.... Arbitrarily setting each of these values as a PDF with a median value of 8.1% does not seem to be a satisfactory solution. In saying this, the SRG is aware that the measurements are difficult to make. [Comment 351, Source Document tec004, Page 046, Section 6.2.2]

the understanding of the instant release process is quantitatively unreliable. [Comment 352, Source Document tec004, Page 047, Section 6.2.2]

OPG RESPONSE

OPG acknowledges the importance of the instant release fraction (IRF). In the EIS and SCS, conservative IRF values were estimated based on experimental data on release of fission products from spent fuel. Because of the importance of the IRF values, it is anticipated that they will be updated for a future assessment for a potenital site, since experiments measuring fission product releases from spent fuel have been reported in the literature after publication of the EIS and SCS reports. The importance of new data was demonstrated in the SCS (Johnson et al. 1996), where new experimental data allowed a better and less conservative estimation of the C-14 IRF. Also, a recent

review of Tc IRFs indicates that the value used in the EIS is too constructive (Garisto and Gierszewski 2002). Also, IRFs will be applied to all nuclides of a particular element, e.g., an IRF for Cs-137 will be defined as was done in the SCS.

Table E-1 of the Vault PRD (Johnson et al. 1994) includes data for only selected radionuclides. The nuclides included in the EIS postclosure assessment are listed in Table 5-4 of the Postclosure Assessment PRD (Goodwin et al. 1994). A current list of reference instant release fractions is available in Garisto (2002).

The validity of the equations in the Vault PRD describing the instant release source term (Johnson et al. 1994, p.135) have been questioned in the review referenced in Comment #2. We believe that these equations are valid, but the description of the model equations was not written clearly. Let us now address the particular questions related to the validity of the equations on page 135 of the Vault PRD (Johnson et al. 1994). Equation 5.5 of the Vault PRD (Johnson et al. 1994, p. 135), which describes the mass balance equation for nuclides in the container void volume, contains a term involving the instant release inventory I0. Confusion may have arisen because I0 was defined as "a unit inventory", whereas it should have been defined as "a unit inventory per container surface area". (Here, the surface area for transport is the container area since in the EIS the container is assumed to disappear completely on failure.) Equation 5.5 is used as a boundary condition to solve Equation 5..4 for the concentration Ci and this solution, in turn, can be used to calculate the rate of release of nuclides out of the container. Since Ci was calculated for unit instant release inventory per container area, the total flux out of all failed containers is equal to:

 $GI(t) = (-D(dCi/dx)A)^{*}(IT/A)^{*}fI$

where A is the container area, IT is the total inventory in all failed containers, fl is the instant release fraction and GI(t) is the same as the term defined in Equation 5.3 of the Vault PRD. This indicates that the equations on page 135 are correct, but that the nomenclature may have been confusing. In any event, this model has been replaced with a better model in the SCS (Johnson etal 1996).

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7.03.03.03.02 Safety Assessment - Postclosure - Vault - Parameters - Diffusion Coefficients

PARTICIPANT COMMENTS

Scientific Review Group

Diffusion coefficients for radionuclides are too low.... a set of parameters, originally considered reliable, have proven not to be so when re-measured experimentally.... AECL has stated that insufficient information exists concerning the diffusion parameters of individual radionuclides. In subsequent sections, statements are made that recent experimental evidence indicates general similarity to exist between parameter values for all radionuclides. This variance is misleading and raises questions as to whether sufficient review has been carried out in the examination of the diffusion properties of radionuclides. [Comment 219, Source Document tec004, Page 201, Section F-2.1.3]

OPG RESPONSE

At the time that the EIS was being prepared, new experimental data became available for the diffusivities and apparent diffusivities of nuclides in buffer and backfill materials. These experiments indicated that surface diffusion effects were not as important as previously thought. Therefore, the buffer and backfill diffusion models used in the SCS (Johnson et al. 1996) and, hence, the diffusivity and Kd data, differed from those used in the EIS (Johnson et al. 1994). Because the two models are different, e.g., in the EIS model, but not in the SCS model, the buffer porosity is nuclide dependent, the diffusion coefficients and capacity factors used in the two models are not directly comparable.

The impact of the revised diffusion data on the EIS dose estimates was investigated in Johnson et al. (1994, p. 269). It was found that the new diffusion data resulted in an increase in the mean-maximum I-129 dose and, hence, the mean-maximum total dose, by about a factor of 2. The increase in the mean-maximum dose rates for C-14 and Tc-99 were larger - about a factor of 4 for C-14 and a factor of 10,000 for Tc-99. However, because the doses from these nuclides were small compared to the I-129 dose, particularly for Tc-99, these latter changes did not affect the mean-maximum total dose.

In the SCS, the measured values of the intrinsic and apparent diffusion coefficients in the buffer and backfill materials were used, where available, in the mass transport calculations for the vault. (The capacity factor is the ratio of the intrinsic to apparent diffusion coefficients.) These data suggested that, for both the buffer and backfill, diffusivity values for all nuclides ranged over a narrow range from 3.2E-4 to 3.2E-3 m2/a (Johnson et al 1996, p16). However, in the recent SR97 assessment (SKB 1999), buffer diffusivities (but not backfill diffusivities) were taken to be nuclide dependent because of so-called anion exclusion effects. In SKB (1999), buffer diffusivities ranged from 3E-5 m2/a for Cl to 3E-2 m2/a for Ni. (Backfill diffusivity data will be reanalyzed to obtain the most reliable values of the nuclide diffusivities and apparent diffusivities in the buffer and backfill materials.

References

Johnson, L.H., D.M. LeNeveu, D.W. Shoesmith, D.W. Oscarson, M.N. Gray, R.J. Lemire and N.C. Garisto. 1994. The disposal of Canada's nuclear fuel waste: The vault model for postclosure assessment. Atomic Energy of Canada Limited Report AECL-10714.

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fuel. SR 97 - Post-closure safety. SKB Technical Report TR-99-06 (Volumes I and II).

7.03.03.03.03 Safety Assessment - Postclosure - Vault - Parameters - Solubility Limits

PARTICIPANT COMMENTS

Atomic Energy Control Board

it is not clear why solubility limits are correlated between contaminants, instead of being simulated mechanistically from chemical parameters, as is the sorption for each contaminant (Postclosure PRD, p. 127). [Comment 599, Source Document gov002, Page 41, Section C.1.1(iii)]

OPG RESPONSE

It is stated in the Postclosure PRD (Goodwin et al. 1994, p. 127) that "In SYVAC3-CC3, we correlate solubility limits for uranium and technetium, and for plutonium, neptunium and thorium, by calculating them as a function of a basic set of sampled parameters that include the electrochemical potential and other fundamental sampled parameters".

The meaning of this statement has been misunderstood. What was actually meant is that the solubilities of uranium, technetium, plutonium, neptunium and thorium are calculated as a function of the fundamental sampled parameters describing the chemical composition of the groundwater in contact with the fuel, e.g., electrochemical potential, pH, temperature, salinity, etc. The solubilities of these elements are, therefore, correlated in the sense that they pertain to the same values of the fundamental solution properties.

References

Goodwin, B.W., D.B. McConnell, T.H. Andres, W.C. Hajas, D.M. LeNeveu, T.W. Melnyk, G.R. Sherman, M.E. Stephens, J.G. Szekely, P.C. Bera, C.M. Cosgrove, K.D. Dougan, S.B. Keeling, C.I. Kitson, B.C. Kummen, S.E. Oliver, K. Witzke, L. Wojciechowski, and A.G. Wikjord. 1994. The disposal of Canada's nuclear fuel waste: Postclosure assessment of a reference system. Atomic Energy of Canada Limited Report AECL-10717.

7.03.03.03.04 Safety Assessment - Postclosure - Vault - Parameters - Buffer Anion Correlation Coefficient

PARTICIPANT COMMENTS

Atomic Energy Control Board

The buffer anion correlation parameter is not explained clearly (Postclosure PRD, p. 127). Its derivation and evaluation are not presented.... it is not clear if this anion correlation parameter applies to sampled or constant parameters. Since this is one of the most important parameters in the postclosure performance assessment, it needs to be better explained. [Comment 600, Source Document gov002, Page 41, Section C.1.1(iii)]

OPG RESPONSE

(Johnson et al. 1994), although it is not referred to as the "buffer anion correlation parameter". In the EIS, the model describing diffusion in the buffer and backfill included a surface diffusion term (Johnson et al. 1994, p. 45). The surface diffusion term depended on the charge of the diffusing species as well as on its Kd value. Because of these dependencies, diffusion coefficients of nuclides having charges of the same sign (either anions or cations or neutral species) were correlated. This correlation was achieved by defining dummy correlation parameters, which were used to correlate the diffusion coefficient values of nuclides in the same group and to correlate the diffusion values with the capacity factor values. (Since the surface diffusion coefficient depends on Kd, the diffusion and capacity factor values are positively correlated). This dummy correlation parameter for anions is referred to as the "buffer anion correlation parameter" in the Postclosure report.

After the EIS was prepared, additional information became available which suggested that surface diffusion is not an important as previously thought in the buffer and backfill (Johnson et al. 1994, p. 46). Thus, in the Second Case Study surface diffusion terms were not used (Johnson et al. 1996) and it no longer became necessary to correlate the different diffusion values. Consequently, the "buffer anion correlation parameter" was not used in the Second Case Study.

Recently, in their review for SR97, Yu and Neretnieks (1997) suggest that surface diffusion is important for Cs, Ps, Sr and Ra in low ionic strength waters and that anion exclusion effects are important for anions such as I-. This would indicate that the buffer and backfill effective diffusion coefficients and (element dependent) capacity factors (the ratio of the effective diffusion coefficient and the capacity factor is equal to the experimetnally measured apparent diffusivity for the element), should be critically reviewed and revised, if necessary, for application to the next Canadian assessment of used fuel disposal in a geologic repository.

References

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Johnson, L.H., D.M. LeNeveu, D.W. Shoesmith, D.W. Oscarson, M.N. Gray, R.J. Lemire and N.C. Garisto. 1994. The disposal of Canada's nuclear fuel waste: The vault model for postclosure assessment. Atomic Energy of Canada Limited Report AECL-10714.

Johnson, L.H., D.M. LeNeveu, F. King, D.W. Shoesmith, M. Kolar, D.W. Oscarson, S. Sunder, C. Onofrei, and J.L. Crosthwaite. 1996. The disposal of Canada's nuclear fuel waste: A study of postclosure safety of in-room emplacement of used CANDU fuel in copper containers in permeable plutonic rock. Volume 2: Vault model. Atomic Energy of Canada Limited Report AECL-11494-2.

Yu, J.-W. and I. Neretnieks. 1997. Diffusion and sorption properties of radionuclides in compacted bentonite. SKB Technical Report, TR 97-12. Stockholm, Sweden.

PARTICIPANT COMMENTS

Atomic Energy Control Board

Contaminant transport through the simplified barriers is simulated inappropriately using a mass transport coefficient (MTC) derived to represent the rate of mass movement across interfaces between the barriers.... It is not shown that modifying the steady state MTC with an Augmentation Factor to simulate transient conditions is conservative or appropriate.... The form of the MTC for convective mass transport does not appear to be realistic.... Assuming no convection in the buffer could result in an underestimation of the MTC.... The use of the MTC to simulate contaminant transport through the buffer and backfill is not described clearly.... Using the larger of the convective and diffusive MTCs is not always conservative.... the MTC method underestimates vault release rates by about two orders of magnitude compared with the Coupled Solution (CS) model and by four orders of magnitude compared with the swept-away (C=zero) method. The conservativeness of the mass transport rate estimates, especially when the discrepancy between the models is orders of magnitude. [Comment 620, Source Document gov002, Page 47, Section C.1.4]

Natural Resources Canada

In the light of the results presented in section 8.3 showing the superiority of the coupled approach, the use of mass transfer coefficients should be reconsidered. [Comment 727, Source Document ph2gov001, Page vau6]

Scientific Review Group

the use of mass transfer coefficients in the MT code to link the components of the vault model to each other, and the vault model to the geosphere model is problematic. Not only are these coefficients assigned subjectively (R-Vault 1994: p.170), but the assigned values are admittedly non-conservative, and they fail to guarantee continuity of the concentrations across the interfaces between system components (buffer, backfill, and rock) (R-Vault 1994: p.176). According to AECL, the approximation to the actual mass transferred at the interface is poor under certain conditions (R-Vault 1994: pp.186, 257), and the coefficient must be augmented in order to yield an acceptable solution. In some cases, mass transfer coefficient values were assigned so as to obtain a desired outcome (R-Vault 1994: p.170). At early time, the mass released is underestimated by as much as two orders of magnitude (R-Vault 1994: p. 257). The SRG questions the adequacy and validity of this approach for predicting the release of radionuclides to the geosphere. [Comment 425, Source Document tec004, Page 071, Section 6.5.2]

The use of large backfill and rock mass transfer coefficients (near-zero concentration in the rock) is not necessarily a conservative approximation.... at earlier times, the mass transfer approach underestimates 129I release rates by up to two orders of magnitude relative to the coupled model, and four orders of magnitude relative to the zero-concentration model! ... The quoted results in R-Vault are for releases over 100,000 years, rather than for shorter periods and/or instantaneous releases. Releases for a range of time spans should have been provided.... AECL has acknowledged that it would be more realistic to use a coupled model which correctly accounts for the continuity of flux and concentrations across the buffer and backfill and backfill and rock interfaces ... Such a coupled model is in fact available ... Yet it "... has not been used in the vault model because of the large computer resources required and because a narrower spectrum of quality assurance tests have so far been applied to it" (R-Vault 1994: p.xiv). Neither of these two reasons are justified or defensible. With present day computer hardware and software, computational limitations should not be cited as an obstacle to complex calculations, especially not in one-dimension. [Comment 216, Source Document tec004, Page 199, Section F-2.1.3]

OPG RESPONSE

OPG accepts the criticisms regarding the use of mass transfer coefficients in the MT code used to describe mass transport through the vault in the EIS (Johnson et al. 1994).

The current OPG vault model (INROC) does not use mass transfer coefficients but uses a coupled model, i.e., the coupled mass transport equations for the buffer, backfill, EDZ and a semi-infinite geosphere zone are solved simultaneously. This vault model is an updated version of the model used in the SCS (Johnson et al. 1996). This new approach is clearer, more transparent and more defensible.

Further developments to improve the geometric detail of this model are presently under evaluation.

References

Johnson, L.H., D.M. LeNeveu, D.W. Shoesmith, D.W. Oscarson, M.N. Gray, R.J. Lemire and N.C. Garisto. 1994. The disposal of Canada's nuclear fuel waste: The vault model for postclosure assessment. Atomic Energy of Canada Limited Report AECL-10714.

Johnson, L.H., D.M. LeNeveu, F. King, D.W. Shoesmith, M. Kolar, D.W. Oscarson, S. Sunder, C. Onofrei, and J.L. Crosthwaite. 1996. The disposal of Canada's nuclear fuel waste: A study of postclosure safety of in-room emplacement of used CANDU fuel in copper containers in permeable plutonic rock. Volume 2: Vault model. Atomic Energy of Canada Limited Report AECL-11494-2.

7.03.03.04 Safety Assessment - Postclosure - Vault - Research PARTICIPANT COMMENTS

Chemical Institute of Canada

It would be useful to carry out some experiments where SIMFUEL surfaces, also containing actinides, are ion bombarded to certain surface defect concentrations and then are exposed to saline anoxic ground water. Some similar work is reported by Matzke (J.Nucl.Mat.190,101-1992) which I am sure is known to the authors of this report. [Comment 2145, Source Document tec005, Page 08, Section II.I.a]

Scientific Review Group

definitive experiments with loaded containers in a simulated disposal environment, under saturated conditions, have not been conducted to address uncertainties relating to the extent of radiolysis. [Comment 2146, Source Document tec004, Page 121, Section B-2.1.5]

OPG RESPONSE

Some work on the effect of additives (rare earths, fission product elements, etc.) on the corrosion behaviour of UO2 fuel has already been carried out (Shoesmith et al. 2001). OPG is currently funding a 5-year Chair position (2000-2005) at the University of Western Ontario. In the scope of work for the Chair position, additional electrochemical experiments using SIMFUEL electrodes will be done.

It is suggested that the extent of radiolysis outside a container has not been treated in sufficient detail. (Radiolysis of water outside container produces oxidants which can react with the container.) However, the discussion in the SCS Vault report (Johnson et al. 1996) indicates that for a copper container, the current OPG reference container, gamma radiolysis effects would be minimal because of the low absorbed dose rates (about 1 Gy/h after 120 years, for a 72 bundle container). This is supported by the work of King and Litke (1987) who did not observe a positive shift in Ecorr of copper in deaerated groundwater at 150C when irradiated with a dose rate of 27 Gy/h (at least 2.5 times the maximum dose rate for a 72 bundle container.) Furthermore, no deleterious effect of gamma radiation at a dose rate of 5 Gy/h has been observed in long-term (up to 5 year) irradiated corrosion tests under simulated Canadian disposal conditions (King and Ryan, unpublished data).

OPG is currently reviewing the reference container design. One key parameter is the radiation field on the outside of the container (which affects dose rate received by workers handling the container). In all of the current preferred candidates, the radiation field is even lower than in the SCS (Hanna and Arguner 2001).

References

Hanna, S. and D. Arguner. 2001. Radiation dose rates from used-fuel containers and attenuation characteristics of selected materials. Ontario Power Generation report 06819-REP-01300-10020-R00.

Johnson, L.H., D.M. LeNeveu, F. King, D.W. Shoesmith, M. Kolar, D.W. Oscarson, S. Sunder, C. Onofrei, and J.L. Crosthwaite. 1996. The disposal of Canada's nuclear fuel waste: A study of postclosure safety of in-room emplacement of used CANDU fuel in copper containers in permeable plutonic rock. Volume 2: Vault model. Atomic Energy of Canada Limited Report AECL-11494-2.

King, F. and C.D. Litke. 1987. The corrosion of copper in synthetic groundwater at 150C. Part 1. The results of short-term electrochemical tests. Atomic Energy of Canada Limited Technical Record TR-428.

Shoesmith, D.W., W.H. Hocking and J.S. Betteridge. 2001. The influence of UO2 fuel composition on its corrosion behaviour under waste disposal conditions. Ontario Power Generation Report 06819-REP-01200-10052-R00.

7.03.04 Safety Assessment - Postclosure - Geosphere

7.03.04.01 Safety Assessment - Postclosure - Geosphere - Conceptualization PARTICIPANT COMMENTS

Atomic Energy Control Board

The use of the equivalent porous medium method to simulate groundwater flow and contaminant transport through sparsely fractured rock has not been shown to be adequate or appropriate.... AECL claims that the URL drawdown experiment "demonstrated the applicability of using the porous media equivalent finite element modelling approach to describe the hydraulic properties of a fractured plutonic rock mass." However, the shaft only penetrated moderately and highly fractured rock (upper 255 m), and did not test the applicability of the approach to sparsely fractured rock. Furthermore, the experiment does not address the ramifications of applying the equivalent porous media method to transport. [Comment 579, Source Document gov002, Page 29, Section B.2.2(ii)]

Canadian Geoscience Council

the characterization-modeling approach taken in the proposal documents (re the Geosphere Model) is presently the best method of coming to an acceptable prediction, but ... because of the complexity of the geological domain, two further steps are essential. These might be given the names "process verification" and "complexity verification". "Process verification" means finding evidence to show that the concepts relied upon in the prediction are correct and sufficiently encompassing to handle the case at hand. "Complexity verification" requires evidence that the simplified representation of the earth used in the modeling is an adequate representation for the task. [Comment 1029, Source Document tec002, Page 09, Section 2.1.3]

there is a conflict between what the groundwater chemistry is saying about deep flows and the assumption in the modeling that long wavelength components in the surface elevation (i.e., the topography) drives and controls the pressure distribution that creates flow cells going to very large depth.... such conflicts must be resolved in any final submission. [Comment 1056, Source Document tec002, Page 21, Section 3.4.3]

[It is assumed that] Type III fracture zones ... can be modeled as an equivalent porous medium (EPM).... This assumption cannot be true in any particular region of a type iii fracture zone, as the authors acknowledge. We are, however, optimistic that breakthroughs in computer models and in computing capacity will allow models that give increasingly accurate results. [Comment 1057, Source Document tec002, Page 22, Section 4.1.1]

[It is assumed that] Purely Darcian, linear laminar flow conditions only will apply. This is another basic modeling convention which may or may not apply in all parts of a type iii fracture zone. It is entirely reasonable that flow can acclerate at least to a non-linear laminar state [Comment 1058, Source Document tec002, Page 22, Section 4.1.1]

[It is assumed that] The only physico-chemical interaction is equilibrium linear sorption.... Grain size effects and partial dissolution of micas and feldspars appears to have been ignored. Such dissolution could be important in selectively enlarging channels in the type ii and iii fracturing, certainly over a span of 10,0000 years. [Comment 1059, Source Document tec002, Page 22, Section 4.1.1]

[It is assumed that] There is complete fluid mixing across fracture planes and at their intersection. This is idealized and unlikely to occur. In our view, it is not a conservative assumption because deviation from it will underpredict the migration paths of components. [Comment 1060, Source Document tec002, Page 23, Section 4.1.1]

New classes of models must be adopted as new ideas emerge. [Comment 1020, Source Document tec002, Page ii, Section ES]

Durham Wetlands and Watersheds

Modelling should have been done for 1 to 2 km below the surface as opposed to 1/2 to 1 km. [Comment 2003, Source Document pub043, Page 5]

Ecosystem Approach Group

the definition of geosphere here (pg.495 [EIS]) does not include energy, although later (pg.100; 112) they mention seismic activity. [Comment 2036, Source Document pub033, Page 09]

Natural Resources Canada

the base model indicates that low-dipping fracture zones terminate at a depth of 1000 metres.... there is no evidence presented indicating that they stop at 1000 metres, or obvious reason why they should. [Comment 730, Source Document ph2gov001, Page geo1]

It is unlikely that fracture size is distributed as the document states and it also physically unrealistic since it implies that a very large fracture shows the same flow rate as a large fracture.... The effects of fractal size distribution on hydrological models should be considered. [Comment 744, Source Document ph2gov001, Page sit4]

It is unclear what criteria are used here to distinguish where a fracture is modelled either explicitly or implicitly. This is important because secondary, yet still significant fractures can provide high permeability connections between major fracture zones. Whether or not these connections are modelled implicitly or explicitly in a numerical model can have a dramatic effect on predicted radionuclide travel times. [Comment 814, Source Document ph2gov001a, Page 15, Section 2.4.1]

We recommend that a better approach for developing a conceptual hydrogeological model would be to use the stochastic or geostatistical technique known as conditional simulation. [Comment 817, Source Document ph2gov001a, Page 16, Section 2.4.1]

the proposed vault is designed to be "suitable for....a highly stressed, sparsely fractured, rock." These high stress magnitudes have been amply documented at Pinawa, where the stress regime is anisotropic. It is not clear to me whether or not this stress magnitude anisotropy and directionality has been incorporated into the models of fluid flow.... The permeability of the modelled fracture zone, for example, will in part depend on its orientation with respect to the orientation and relative magnitudes of the principal stresses acting on the surrounding rocks. [Comment 831, Source Document ph2gov015, Page 17]

Northumberland Environmental Protection

in the REFERENCE CASE STUDY 1, the assumptions are conservative (except for the hypothetical WEZ! which renders the case in terms of feasibility, undemonstrated, undocumented and invalid.) [Comment 1500, Source Document cs027, Page 1]

Northumberland Environmental Protection (Fairlie)

A recent international comparison (Neall et al, 1994) of HLW performance assessments in five other countries draws particular attention to unconservative assumptions in the AECL geosphere model which contains a large diffusion barrier compared with other models. These assumptions include the use of low Darcy velocities in sparsely fractured rock, little or no advection transport, low hydraulic gradient, and low angle of fault. The result is that groundwater travel times in the AECL geosphere model are 104 greater than in other geosphere models. Another example is the dilution of the nuclide inventories by the extensive volume of the proposed vault: this dilution is not used in other repository assessments. [Comment 1347, Source Document ph2tec006, Page 05]

Northwatch (Richardson)

The use of the porous medium methodology by AECL tends to reduce the effects of heterogeneities not only within the rock mass (which AECL actually tend to ignore) but within the actual flowing fractures themselves. [Comment 1520, Source Document ph2pub009, Page 13, Section 3]

It is perhaps understandable that AECL finds itself unsure of how to approach the modelling of flow. It appears that the international community is still far from actually achieving the so-called "consensus" often claimed by AECL and others, on this issue in particular.... AECL should ... discuss how these uncertainties are being approached in other countries, and how they intend to overcome them. [Comment 1521, Source Document ph2pub009, Page 13, Section 3]

OECD/NEA Review Group

In most other hard-rock programmes, the possibility of advective flow near the tunnel is allowed for. Since AECL also wishes to include more fractured host rocks as candidates for repositories, analyses of this type will eventually be needed. [Comment 1205, Source Document tec001, Page 08, Section 3.1.4]

Scientific Review Group

The assumption that flow is downward in the vicinity of the shafts (R-Vault 1994: p. 172), while transport out of the vault is generally upward, is fully dependent upon the local topography of the WRA site and therefore has no applicability to a generic concept. The purpose of this assumption would appear to be to support the requirements of the 1D model. In the absence of local topographic highs, the justification for omitting the shafts from the model would depend entirely on the performance of the shaft seals. [Comment 520, Source Document tec004, Page 050, Section 6.2.3]

Assumptions about the transport properties in the rock, particularly the assumption of uniform transport properties in moderately fractured rock and the assumption that diffusion is the dominant transport mechanism, are unjustified.... nothing is said about how these transport properties may be evaluated. It has not been sufficiently demonstrated that, at very low hydraulic gradients over very long time periods, significant flow will not take place through fractures.... A key question that arises in this context is: Can a repository location be found in the rock such that even if the vault were not fully surrounded by unfractured rock, the contaminant travel time to the surface would still be thousands of years or more? [Comment 21, Source Document tec004, Page 112, Section A-2.2.3]

The concept of three distinct fracture domains (R-Siting 1994: p.54) is overly simplistic and misleading. There is a continuum between intra-granular cracks and large fault zones. The boundaries separating the three domains are arbitrary, subjective and poorly defined. [Comment 22, Source Document tec004, Page 113, Section A-2.2.3]

the SRG has concluded that there is ample and irrefutable published evidence from crystalline rocks at ... that fracture density, whether open or otherwise, shows, at best, extremely poor correlation with permeability; and therefore, is a poor indicator of permeability ... Accordingly, the SRG is of the opinion that it is inappropriate to assign uniform permeabilities to the domains in Figure 1.4.2 (R-Geosphere 1994: p.20), and to the horizontal layers in Figures 5.3.3 (R-Geosphere 1994: p.110), and 5.4.1 (R-Geosphere 1994: p.115), and especially to assign a uniformly low permeabilities to the deepest domains of sparsely fractured rock solely on the basis of undocumented assertions about intensity of fracturing. Furthermore, the distribution of the three rock types ... is not documented in this primary reference document with observations made from boreholes at the site; and moreover, borehole information on variations in degree of fracturing with depth that is presented in the R-Siting Primary Reference Document (see below) contradicts the pattern of distribution of fractured rock in the conceptual model upon which the MOTIF and GEONET models are based. [Comment 235, Source Document tec004, Page 215, Section G-3.1.2]

At the local scale of the WRA the document does not provide the necessary geoscience data to justify: i) the configuration of the hydrogeological model (e.g. horizontal layering of permeability): High kvalues may persist to form preferential flow channels at all depths; and this is not considered in MOTIF.

ii) the hydrogeological parameters used in the model: It is extremely difficult to ascertain the reliability of the conceptual model because there is little reference to actual data or data sources. This lack of hard data support for the model is most glaring when it comes to critical parameters such as permeability and porosity, especially in the sparsely fractured rock.... In the absence of reliable data, it must be considered inappropriate to assign uniform permeabilities to the horizontally layered domains, and especially to assign a uniformly low permeability to the deeper domains of sparsely fractured rock, solely on the basis of intensity of fracturing. [Comment 240, Source Document tec004, Page 217, Section G-3.2.1]

The conclusion that contaminant transport is dominated by diffusion in the sparsely fractured rock is unjustified: The conclusion (R-Geosphere 1994: p.254) that "diffusion dominates contaminant transport for all pathway segments in the lower rock zone" is not justified on the basis of measurements or theoretical arguments. The claim for the dominance of diffusion appears to depend upon unsubstantiated assumptions concerning permeability and effective porosity in the sparsely fractured rock [Comment 249, Source Document tec004, Page 221, Section G-3.2.14]

Thus the new information provided by AECL indicates that groundwater flow in the geosphere at the Whiteshell Research Area comprises two systems: a very slowly moving component in the sparsely fractured low-permeability rock that is driven by relict pressure gradients, and a relatively fast component in the surrounding higher-permeability fractured-rock network that is driven by present-day topographic gradients. This dual flow system mechanism in the geosphere, as well as the potential implications of advective transport in the sparsely fractured rock, have not yet been recognized nor analyzed by AECL. Before designing a repository, it will be necessary to formulate an appropriate conceptual model and to develop a fundamental understanding of the controlling mechanisms of flow and transport in this type of system. In particular, it will be necessary to understand the effect of the vault excavation and the heat source on the long-term transient pore pressure profile and the transport of the saline water, as well as the combined effects of these processes on the potential migration of radionuclides under the advective transport regime apparently prevailing in the sparsely fractured rock. [Comment 524, Source Document tec004a, Page 11, Section 2.5]

The conceptual model ... is fundamentally flawed because it misinterprets the data in a serious way by failing to recognize the apparent dual and locally transient character of the groundwater flow system.... the new data suggest that the groundwater flow system comprises a relatively fast component, which is driven by topographic gradients and controlled by a network of interconnected moderately fractured rock and fracture zones, and a slow transient component, which exists within blocks of sparsely fractured rock embedded within this network, and which is driven apparently by relict (geological) pressure gradients.... The AECL conceptual model overrepresents the continuity of the sparsely-fractured rock and underrepresents the hydraulic communication between high-permeability moderately fractured rock and fracture zones It incorrectly assumes that transport in the sparsely fractured rock is diffusive, while the data clearly suggest that saline water, under the influence of high pressure gradients, is moving advectively out of the blocks of low-permeability, sparsely fractured rocks in all directions, albeit at a very slow rate.... [Comment 532, Source Document tec004a, Page 15, Section 3]

The AECL conceptual model assumes that fracturing decreases with depth, when in fact the data presented by AECL indicate that fractures may occur at all depths that were investigated (Stevenson et al. 1996a: Figures 7 and 8; Stevenson et al. 1996b: Figure 3). In general, the AECL permeability data given in these documents show considerable scatter that may be qualitatively interpreted either as no significant trend below 200 m, or as only a very weak trend of permeability decreasing with depth. The data base itself is too small to allow any meaningful statistical inferences. The permeability trend line assumed by AECL generally underestimates permeability, both for the sparsely-fractured rock and for the fracture zones, sometimes by several orders of magnitude. [Comment 533, Source Document tec004a, Page 16, Section 3]

the geosphere for the new case study is not based on actual data and the resulting conceptual model, therefore, has no practical relevance within the context of a viable multiple-barrier system. [Comment 534, Source Document tec004a, Page 16, Section 3]

In order to provide the capability to perform a credible quantitative performance assessment of the disposal concept, a realistic conceptual model of the geosphere that reflects actual conditions as indicated by AECL's borehole data should be developed. Such a model will be required in the later stages of a site selection program when a site must be evaluated with respect to contaminant travel times from the vault to the surface, as well as in the final performance assessment of a site once it has been chosen.... the conceptual model must be sufficiently flexible to accommodate any conditions that might be expected.... the SRG doubts that the basic components of the methodology available to AECL at this time are adequate for the task [Comment 535, Source Document tec004a, Page 16, Section 3]

OPG RESPONSE

It is acknowledged that conceptual model development is a key component of future site characterisation and modelling activities. The conceptual model provides a basis to articulate geometry and spatial distribution of flow system properties and boundary conditions relevant to flow and transport. It further provides guidance for identifying processes and mechanisms likely to most influence geosphere barrier performance, for justifying model approximations (i.e. discrete fracture; discrete feature, single or dual equivalent continuum or hybrid) and for rationalizing research and development activities to best support performance assessment assertions.

Development of a conceptual flow system model requires the integration of multi-disciplinary site characterisation data using a systematic and internally consistent framework. To this end the Canadian program is exploring the application of visualization software (VULCAN; GoCad) and geostatistical tools to explore and define spatial correlation/up-scaling amongst data sets and better communicate spatial sub-surface geometry essential to performance assessment. In addition, geoscience research activities have focused on improving the understanding of flow system evolution, for example in studies designed to assess long-term climate change, design basis glacier scenarios and paleohydrogeologic studies of fracture infill mineralogy that may preserve evidence of past fracture fluid composition and boundary conditions. Further, research supporting fundamental assertions in the conceptual model regarding either groundwater flow or mass transport have also been undertaken. Examples include the In-situ Diffusion experiment designed to advance the fundamental understanding of diffusive transport/matrix diffusion in sparsely and moderately fractured rock and the Whiteshell Research Area Hydrogeochemistry Assessment in which elemental and isotopic data are combined to evaluate flow system evolution and provide estimates of groundwater residence times. This revised approach and response to conceptual model development is intent on strengthening the repository safety case and improving the clarity and transparency of geosphere performance assessment outcomes.

7.03.04.02 Safety Assessment - Postclosure - Geosphere - Models

7.03.04.02.01 Safety Assessment - Postclosure - Geosphere - Models - GEONET

7.03.04.02.01.01 Safety Assessment - Postclosure - Geosphere - Models - GEONET -General

PARTICIPANT COMMENTS

Atomic Energy Control Board

Verification work to show that GEONET adequately represents the more-detailed MOTIF models for the hypothetical site is limited to a comparison of a portion of the two-dimensional site model only (Chan et al, 1991, Figure 2). Three-dimensional groundwater flow modelling of the hypothetical site shows that significant flow occurs perpendicular to the plane of the two-dimensional model, and that the minimum groundwater travel time from the vault to ground surface in the three-dimensional model was about half that in the two-dimensional model (Geosphere PRD, p. 156). Thus, a two-dimensional model does not provide an adequate representation of groundwater flow patterns for the hypothetical site for the verification of GEONET. [Comment 623, Source Document gov002, Page 52, Section C.2.3]

the sensitivities of the GEONET model outputs to hydrogeological and geochemical parameters are not compared to the corresponding sensitivities from the more-detailed analyses with MOTIF. In other words, AECL does not demonstrate that GEONET adequately reproduces the underlying sensitivities in the more detailed modelling. [Comment 625, Source Document gov002, Page 52, Section C.2.3]

Environment Canada

there is also concern about ... the lack of any verification of the GEONET code by the MOTIF code for the case of a three-dimensional flow field [Comment 855, Source Document gov003, Page 20, Section 2.9]

Natural Resources Canada

Being based on a single conceptual model of site geology, GEONET therefore cannot consider uncertainty in particle paths. This ignores the fact that alternative conceptual models and flow paths may also be interpreted from available data, because of the uncertainty due to geological heterogeneity. Given that geological heterogeneity is recognized as the greatest cause of uncertainty in particle travel times, this failure represents a severe limitation of the GEONET model. [Comment 733, Source Document ph2gov001, Page geo5]

manual and subjective interfacing with MOTIF make it impractical to consider uncertainty in the flow paths themselves through detailed flow modelling on multiple alternative conceptual models of the geosphere ... the subjective, human element involved in the interfacing cannot be accounted for when GEONET is used within a SYVAC probabilistic assessment study ... the 1D flow paths determined through this human interfacing are not perfectly reproducible by independent verification. The manual MOTIF-GEONET interface is inappropriate as part of a rigorous probabilistic post-closure risk assessment model. [Comment 739, Source Document ph2gov001, Page geo8]

The range of possible different radionuclide pathways that can be sampled in the Monte-Carlo simulation is artificially restricted to a skeletal network allowing only 4 outlets to the biosphere; the network layout itself is based on subjective human judgment thereby possibly introducing an a priori bias into the pathway sampling procedure. Thus, it is unclear to what extent GEONET is able to consider, in an unrestricted and unbiased manner, the geological uncertainty associated with radionuclide pathways. [Comment 777, Source Document ph2gov001, Page pos3]

The radionuclide transport models implemented within the geosphere ... [model] do not adequately describe radionuclide travel times (and dose estimates) because of unrealistic flow paths and failure to properly consider the natural variability and uncertainty in hydrogeological parameters. [Comment 812, Source Document ph2gov001a, Page 13, Section 2.4.1]

We recommend that a better approach for developing a conceptual hydrogeological model would include the following elements: 1) removal of the well model from GEONET and treatment of well intrusion scenario outside main SYVAC analysis; 2) removal of the need for a manual interface with MOTIF; and 3) greater consideration of the effects of geological heterogeneity and uncertainty. [Comment 815, Source Document ph2gov001a, Page 15, Section 2.4.1]

We recommend that those elements of the current safety assessment methodology related to the geosphere model and GEONET in particular, not be accepted for site-specific studies during the "site evaluation" stage of the siting process. [Comment 816, Source Document ph2gov001a, Page 15, Section 2.4.1]

Scientific Review Group

The SRG disagrees with the assumption that transport through the geosphere can be effectively represented by a series of one-dimensional advective and diffusive migration paths that are invariant in time, as in the AECL geosphere model GEONET.... Changes in the flow regime due to changes in the initial and boundary conditions or sources cannot be realistically represented. Spatial and temporal changes in groundwater density due to salinity and temperature variations likewise cannot be taken into account. [Comment 376, Source Document tec004, Page 056, Section 6.3.1]

The fixed GEONET network of pathways also means that probabilistic sensitivity analyses with respect to the spatial variability of flow system parameters such as permeability, which would lead to variations in the velocity field, cannot be performed. [Comment 377, Source Document tec004, Page 056, Section 6.3.1]

The SRG disagrees with the conclusion that the GEONET methodology is an appropriate tool for repository performance assessment because the one-dimensional network of fixed pathways used by GEONET must be selected manually from the output of a three-dimensional flow model. Such selection is a subjective, difficult and time-consuming procedure. This procedure precludes meaningful sensitivity analy-ses involving realistic flow parameters. A repository location that differs from that originally assumed can be investigated only by changing the structure of GEONET. Thus the methodology developed for the geosphere performance assessment is poorly suited for determining the effects of flow and transport parameter variability, as the fixed nature of the GEONET network presents a disincentive for comparing scenarios having differing hydrogeologic characteristics. [Comment 378, Source Document tec004, Page 056, Section 6.3.1]

GEONET is not suitable in the context of an iterative siting process where different vault locations within a flow system are to be investigated. Nor is it suitable for comparing the potential performance of different candidate sites. [Comment 379, Source Document tec004, Page 056, Section 6.3.1]

Because pumping is inherently transient, the SRG questions whether a pumping from a well can be accommodated in a valid way within the fixed GEONET network. The SRG also questions whether a single scaling factor (R-Geosphere 1994: p.383) can properly represent the fraction of contaminant captured by such a well. [Comment 381, Source Document tec004, Page 057, Section 6.3.1]

GEONET ... is unsatisfactory for comparing alternative flow paths or variations in the flow system with time. [Comment 382, Source Document tec004, Page 057, Section 6.3.1]

GEONET ... for the case of diffusive transport through the rock, the SRG has not found a clear definition of the cross-sectional area of rock (perpendicular to the direction of transport) a segment would represent. Definition of the cross-sectional area is essential for the calculation of concentration of contaminants and for defining the rock mass available for sorption in the one-dimensional diffusive segments. [Comment 426, Source Document tec004, Page 072, Section 6.5.3]

A major weakness in the geosphere model ... is the fact that GEONET is hardwired to a specific set of flow paths that are obtained by manual interpretation from MOTIF (R-Postclosure 1994: p. 99-100) on the basis of a deterministic simulation of the reference scenario.... The rigid model structure also means that the model developed for the reference site cannot be applied to other sites without extensive modification or redesign (R-Postclosure 1994: p. 71). [Comment 164, Source Document tec004, Page 181, Section E-3.1]

because of the deterministic nature of the transport paths the output from GEONET can only provide a limited probabilistic assessment of certain parameters, not a fully probabilistic assessment of a site. [Comment 231, Source Document tec004, Page 212, Section G-1.2]

The manual interface between MOTIF and GEONET is subjective and inefficient, and the patterns of GEONET flow lines are arbitrary and unreliable... the generality of the MOTIF solute transport and heat transport modules is discarded and replaced by the drastically simplified procedure of GEONET, which includes a subjective manual development of one-dimensional pathways. In the sparsely fractured rock the patterns are determined purely on the basis of diffusion within a nominal concentration field. Any variations in the concentration field that might affect these diffusive paths are ignored in GEONET. [Comment 247, Source Document tec004, Page 220, Section G-3.2.11]

GEONET cannot take into account density effects on groundwater flow due to variations in temperature and salinity No clear rationale is given for omitting an examination of density effects on groundwater flow due to temperature and salinity variations.... AECL's motivation for assuming isothermal and non-saline conditions in GEONET appears to have been based on a desire to accommodate the model to available computing resources. The rationale for omitting the effect of the waste-generated heat in model simulations of contaminant transport through the geosphere came from an experiment, based on MOTIF (R-Geosphere 1994: p.176), that showed this effect to be negligible as long as a zone of sparsely fractured rock at least 46 m thick (the waste exclusion zone) separated the repository from the Fracture Zone LD-1. If the integrity of the waste exclusion zone becomes questionable ... this assumption becomes invalid. [Comment 248, Source Document tec004, Page 221, Section G-3.2.13]

The analysis of pumping test results is flawed... Since the entire flow pattern can change, sometimes drastically, it is inconsistent to define the basic structure of GEONET on the basis of a MOTIF run which does not include a pumping well, and then to account for such a well merely by modifying the velocities along existing GEONET segments and adding a few special segments in the immediate vicinity of the well. A consistent analysis would require the creation of a new GEONET corresponding to each choice of well depth and pumping rate. [Comment 250, Source Document tec004, Page 221, Section G-3.2.15]

As for GEONET, this code is fundamentally unsuited for use in a credible geosphere performance assessment because it is strictly limited to steady-state flow.... GEONET should be abandoned. [Comment 537, Source Document tec004a, Page 17, Section 3]

OPG RESPONSE

An independent review of contemporary geosphere performance assessment models was recently conducted for the OPG program (Novakowski 2000). This review echoed the concerns noted in the above comments, and provided some additional perspectives and program recommendations.

Some of the recommendations noted that line-element network geosphere models were employed as part of a number of other national safety assessments. But the use of such models should be dependent on inclusion of all relevant processes, and in particular solution to the flow equations. The use of improved line-element models should also be supported by more extensive validation tests, and by clear procedures to transfer information from detailed site models to these simplified models. The Canadian program is presently considering the usefulness of such improvements to the present GEONET model, or alternatives based on more faithful representation of the geometry.

However, both the EIS reviewers and the above reviewer noted that fully three-dimensional models are available which can accommodate flow and transport through porous media and discrete fractures in an integrated manner, including sampling of uncertain parameters. Although such models have been used as part of safety assessments in the past (e.g. MOTIF in the EIS case, TOUGH for Yucca Mountain, HYDRASTAR for SR97), they are expected to become a more important part of the analysis. It is intended that future Canadian safety assessments for a deep geologic repository will be more heavily based on such codes. These would be used, for example, to demonstrate a clear link to siting information and to explore the effects of uncertainties in geosphere characterization, for example, through either geostatistical analyses or through a set of alternative deterministic conceptual geosphere models.

References

K.S. Novakowski. 2000. A review of geosphere performance assessment methodologies. Ontario Power Generation report 06819-REP-01300-10008-R0.

7.03.04.02.01.02 Safety Assessment - Postclosure - Geosphere - Models - GEONET -Velocity Scaling Factor

PARTICIPANT COMMENTS

Environment Canada

there is also concern about ... the limitations of velocity scaling factors used in GEONET [Comment 854, Source Document gov003, Page 20, Section 2.9]

Natural Resources Canada

a random "velocity scaling factor" can be applied uniformly to all velocities in order to give some effect of velocity uncertainty. Although this method is consistent with the decision to fix flow paths once and for all, it is a very poor substitute for proper modelling of velocity uncertainty due to permeability heterogeneity. [Comment 734, Source Document ph2gov001, Page geo5]

the groundwater velocity scaling factor ... being a "fudge factor" having meaning only within the context of the GEONET model, it cannot be observed experimentally and its pdf reflects the opinion of AECL experts alone. The choice of pdf has not been justified here or in the document on the geosphere model although its bounds of 0.1 and 10 are quite debatable.... the importance of the groundwater velocity scaling factor does not appear to have prompted any ... re-examination of the model for convective transport. This is surprising since the groundwater velocity scaling factor has, by the authors own admission, a rather complicated and poorly understood effect on ADEs (p.167; p.573; p.617) [Comment 780, Source Document ph2gov001, Page pos4]

Scientific Review Group

The SRG questions the validity of the assumption that uncertainty in the spatial variability of hydrogeologic parameters can be accounted for by random sampling of a single velocity scaling factor. A random spatial variation of a hydrogeologic parameter such as permeability would lead to corresponding variations in groundwater velocity. The latter would vary from point to point, in both magnitude and direction, increasing in some places and decreasing in others. The velocity scaling factor does not allow for the changing of diffusive paths to advective paths. The velocity scaling factor cannot account for variations in boundary conditions, source functions, or changes in the flow field due to heat or salinity differentials. Furthermore, even if the approximation were valid, the two-order-of-magnitude range (R-Postclosure 1994: p.226) allowed by AECL for variation in the velocity scaling factor is too small, in the view of the SRG, to give a meaningful representation of the large variations in groundwater velocity that may occur in a fractured system. Finally, AECL does not show whether or not the overall fluid mass balance in the system is still satisfied when the fluid velocity is increased or decreased everywhere in the system. Accordingly, the velocity scaling factor is not an adequate representation of flow system variability. [Comment 380, Source Document tec004, Page 056, Section 6.3.1]

By means of the velocity scaling factor, the velocity everywhere in the GEONET model is either increased or decreased by the same multiplier, within a range of two orders of magnitude of the mean (R-Postclosure 1994: p.226).... this procedure is of highly questionable validity for the following reasons ... The velocity factor is therefore an artifact of the modelling procedure and/or hardware. The high frequency of occurrence of this artifact throughout the report is an example of the model driving the analysis. For the above reasons, results obtained on the basis of the velocity scaling factor are of dubious value. [Comment 179, Source Document tec004, Page 186, Section E-3.1]

OPG RESPONSE

This approach was used in the EIS assessment, but was not used in the SCS assessment, and will not be used in future safety assessments.

7.03.04.02.02 Safety Assessment - Postclosure - Geosphere - Models - MOTIF PARTICIPANT COMMENTS

Atomic Energy Control Board

The extent to which the URL drawdown experiment can be used as a validation case for MOTIF is limited.... it is important in blind experiments for a complete description of the model and the modelling results to be submitted to a third party (and preferably published) prior to the start of the experiment. It does not appear that this was done.... To date, a detailed description and justification of the model structure and parameterization based on the available field data has not been published.... it appears that the local scale model used in the predictions was changed around the time that the experiment started, and AECB staff have not been able to confirm in the available literature that the new model was in place and used prior to the start of the experiment.... it is important to note that the shaft was sunk to a depth of 255 m during the experiment, and thus it tested MOTIF for moderately to highly fractured rock conditions only.... As such, the URL drawdown experiment did not test the applicability of MOTIF and the equivalent porous media approach to modelling groundwater flow and contaminant transport across sparsely fractured rock, such as the waste exclusion zone.... AECL has been slow to report on the comparison between the measured and predicted drawdowns from the experiment.... Furthermore, Davison et al. (1995) showed discrepancies between measured and predicted heads that were higher than AECB staff had anticipated based on previous AECL accounts of the comparison.... While these discrepancies may not be out of line with the capabilities of groundwater modelling technology given the computational constraints and the data available in 1984, the statements in the EIS documentation do not reflect the magnitude of the discrepancies. [Comment 621, Source Document gov002, Page 49, Section C.2.1]

Decisions on the representation of features in three-dimensional MOTIF groundwater flow models are based in part on two-dimensional MOTIF modelling, even though subsequent work has shown that the flow system for the hypothetical site is clearly three-dimensional.... The two-dimensional model was used to assess the impacts of a number of uncertainties in site features on convective transport from the vault.... AECL's preliminary three-dimensional modelling showed, however, that the groundwater flow system for their hypothetical site is clearly three dimensional.... Furthermore, particle tracking shows that there are also significant differences between the two- and three-dimensional flow fields in the plane of the two-dimensional model.... all conclusions drawn with the two-dimensional groundwater flow model. [Comment 626, Source Document gov002, Page 53, Section C.2.4]

Canadian Geoscience Council

Faster machines or more elegant codes must be used in order to realistically represent the highly heterogeneous fractures and fracture zones around the real vault situation. [Comment 1062, Source Document tec002, Page 23, Section 4.1.2]

[MOTIF] has been verified numerically but only in a limited physical way. [Comment 1063, Source Document tec002, Page 23, Section 4.1.2]

In studying the many flow path prediction we were very surprised to see that many of them show segments of travel along the permeability boundaries (see for instance page 155 (geosphere model) Figs 5.5.7 and 8. This seems unphysical, and we assume it is a program artifact, but such results substantially reduce confidence in other results. [Comment 1065, Source Document tec002, Page 25, Section 4.1.2]

Northwatch and Saskatchewan Environmental Society (Richardson)

Since my earlier submission, I have noted the completion of AECL's regional groundwater modelling exercise for the Whiteshell area, as described by Stevenson et al ... It is true to say that it demostrates AECL's abilities to conduct such an exercise, and to apply state-of-the-art characterisation techniques. [Comment 1600, Source Document ph2tec037, Page 15, Section 4.2]

Scientific Review Group

an evaluation or partial validation of the flow component of MOTIF ... provided assurance that the model embodied in the MOTIF computer code is a proper representation of the flow in the fractured rock; however, it is not a validation of the model with respect to flow in other less permeable parts of the rock mass. [Comment 422, Source Document tec004, Page 070, Section 6.5.1]

MOTIF could be made more computationally efficient by updating its matrix solvers (R-Geosphere 1994: p.71), which appear to be obsolete by present standards. [Comment 423, Source Document tec004, Page 070, Section 6.5.1]

To replace GEONET with MOTIF would involve at least:

- improvement of the efficiency of the code by implementing recent advances in numerical techniques (e.g. high-speed matrix equation solvers, and simplified element types);

- automatic grid generation to facilitate the efficient analysis of different scenarios including a variety of repository locations and rock/fracture configuration (the lack of a grid generator might explain the apparent reluctance of AECL to analyze alternative vault locations.);

- good graphic visualization to facilitate the rapid evaluation of generic scenarios;

- embedding MOTIF within the total systems model (e.g. SYVAC3);

- improved treatment of sorption; and

- a probabilistic treatment of its parameters and inputs. [Comment 232, Source Document tec004, Page 213, Section G-2.2]

A more powerful MOTIF code would also have been highly useful in investigating the effects of changes in the location of the repository within the regional groundwater flow system, and in accounting for spatial and temporal variations in fluid salinity. MOTIF should have continued to be developed to a state where it could have been used directly for stochastic analyses by simulation, and to run under SYVAC. In the view of the SRG, it is preferable to run a smaller number of simulations with a scientifically dependable code such as MOTIF, than a large number of simulations with an indefensible code such as GEONET. [Comment 233, Source Document tec004, Page 213, Section G-2.2]

MOTIF does not take into account limitations on sorption due to available surface area In Equation 3.7 (R-Geosphere 1994: p.61) the retardation factor (R) is based on the density of the solid phase rather than on specific surface area as one would expect in fractured rocks. This specific surface area is very small in sparsely fractured rocks, and is made even smaller by channelling. Hence Equation 3.7 overestimates the retardation of sorbing species, and is thus non-conservative. [Comment 246, Source Document tec004, Page 220, Section G-3.2.8]

a new document ... raises serious doubts about the validity of MOTIF. Moreover, the application of MOTIF to the extended Whiteshell Research Area site (Ophori et al. 1996), reveals errors in the application itself ... as well as doubtful results ..., while the application to the new case study ... reveals behaviour inconsistent with physical reality ... Furthermore, the application to the extended WRA site was severely constrained in the level of detail that could be represented because of the inherent limitations in the capacity of the code.... performance assessment of a future real site will require efficient automatic grid generation techniques that are not available with MOTIF.... its usefulness in the future, which will present different and more stringent requirements, is in doubt. [Comment 536, Source Document tec004a, Page 16, Section 3]

OPG RESPONSE

The application of numerical codes to predict groundwater flow and transport in a fractured plutonic Canadian Shield setting is a complex undertaking. The Deep Geologic Repository Technology Program (DGRTP) has undertaken a number of initiatives to further advance and test the application of such 3-dimensional codes in this regard. Key elements in the program strategy include:

1) continued Quality Assurance documentation of MOTIF;

2) evaluation of alternative and complementary 3-dimensional performance assessment groundwater flow/transport codes;

- 3) application of alternative site characterisation modelling strategies
- 4) increased national geoscience communication; and
- 5) maintain international PA program awareness.

MOTIF was developed by the Canadian Nuclear Fuel Waste Management specifically for analysis of groundwater flow and transport in fractured Shield settings. As part of the DGRTP, work has continued to ensure the completion of Quality Assurance documentation for MOTIF, including theory, user and verification manuals. Further, MOTIF continues to be applied in comparative numerical studies such as the Underground Research Laboratory Moderately Fracture Rock Experiment, the international DECOVALEX III coupled Thermal-Hydraulic-Mechanical modelling program and the Insitu diffusion experiment. These activities are intended to provide opportunities for code and experimental result comparison that will continue to demonstrate the utility and capabilities of MOTIF.

In addition to MOTIF, the DGRTP is exploring the application of alternative 3-dimensional flow and transport codes. The purpose is to test and evaluate advances in numerical code development that may improve application for geosphere PA. Such advances include the development of new fast robust sparse matrix solvers for unstructured meshes, fully implicit control volume finite element algorithms, primary variable switching, flux limiters to control numerical dispersion on coarse meshes and efficient time stepping procedures. The application of such codes as Integrated Hydrologic Model (InHM) and FRAC3DVS through the Moderately Fractured Rock Modelling Task Force and a Regional Flow System analyses will examine the ability of codes to mesh complex 3-dimensional geometries, include gravity and density gradients, accommodate temporal and spatial boundary conditions, improved realisation of spatial sub-surface variability, and perform transport calculations at time and space relevant to repository safety. The testing of such codes in co-operative forums such as the MFR Modelling Task Force will improve communication on issues of most relevance to code application. DRGTP monitoring of international progress in PA numerical model development provides another line of assurance that modelling techniques will remain current and state-of-science.

7.03.04.02.03 Safety Assessment - Postclosure - Geosphere - Models - TRACK3D PARTICIPANT COMMENTS

Atomic Energy Control Board

The TRACK3D modelling results appear suspect. In some cases predicted pathlines differ from what would be expected based on hydrogeological theory, and AECL and Ontario Hydro documentation suggest that oscillations and aberrations exist in some predicted pathlines. The TRACK3D pathlines are used in the construction of the GEONET network, and thus they represent a key input to the SYVAC postclosure safety calculations. [Comment 622, Source Document gov002, Page 50, Section C.2.2]

Scientific Review Group

The TRACK3D verification is generally adequate, but it reveals that the code may not be robust (R-Geosphere 1994: pp.99, 478). [Comment 421, Source Document tec004, Page 070, Section 6.5.1]

the particle tracking code TRACK3D may not be fully reliable. Some of the results (R-Geosphere 1994: pp.133, 155, 165) suggest that the code suffers from numerical problems when particle tracks cross from rock blocks to fracture zones which have widely different permeabilities, or when they approach an interface between layers. [Comment 424, Source Document tec004, Page 070, Section 6.5.1]

OPG RESPONSE

In developing the geosphere performance assessment model, GEONET a sequence of activities is conducted. Initially, the conceptual flow system model is discretized into a finite element mesh to allow simulations of groundwater flow for given temporal and spatial flow system properties and boundary conditions. This was achieved in the Environmental Impact Statement and Second Case Study through the used of the Thermal-Hydraulic Mechanical code MOTIF. Once calibrated to field observations, estimates of advective transport pathways are estimated with TRACK3D. These pathways or particle trajectories are computed on material properties and head distributions as computed with MOTIF. The computed pathways form, in part, the rationale for establishing the interconnected 3-dimensional network of 1-dimensional stream tubes used by GEONET to predict radionuclide transport and biosphere response functions. A notable exception is the situation where diffusive transport is dominant in which case GEONET pathways are oriented in the direction of greatest concentration gradient. Precautions are taken in transferring the interpretation of TRACK 3D pathways into GEONET although it is acknowledged that in certain instances, for example material interfaces with significant permeability contrasts, computational artifacts may marginally effect particle pathway results. This is not anticipated to materially effect predicted GEONET outcomes.

While the performance assessment involving the application of MOTIF-TRACK3D-GEONET(SYVAC) provides a methodology to assess the performance of the geosphere barrie, the necessity for manual and subjective decisions at model interfaces can be problematic in terms of dimensionality and traceability. The Deep Geologic Repository Technology Program (DGRTP) is examining the application of alternative 3-dimensional performance assessment modelling approaches that lend improved continuity with site characterisation data and flow system conceptualisation, as well as an integrated code capability to estimate radionuclide transport at time and space scales relevant to repository safety. Examples of such DGRTP research activities in which models are being tested include the Regional Flow System Analyses and the Moderately Fractured Rock Modelling Task Force. The application of these new and innovative modelling approaches is intent on complimenting existing methods as describe above. Eventual comparison of alternative methods will instill confidence in geosphere performance assessment modelling processes and demonstrate to external reviewers inherent uncertainties and utility of various approaches.

7.03.04.02.04 Safety Assessment - Postclosure - Geosphere - Models - Well Model PARTICIPANT COMMENTS

Natural Resources Canada

the detail or spatial resolution implied by the well model is much greater than that of the underlying network model of the geosphere. Since the resolution of a model as a whole cannot be greater than that of any of its parts, the refinement provided by the well model analysis is not justifiable.... sensitivity analyses ... show that human decision parameters related to well construction and operation have a large effect on ultimate human exposure to radionuclides. When these human decision parameters are considered alongside geosphere parameters in the same model, the significance of the former tends to overshadow that of the latter. From this, it could be concluded, wrongly, that detailed modelling of the geosphere is unnecessary.... well models are best handled using a continuum representation of the geosphere. In order for them to be accommodated by a network representation, a large number of more or less ad-hoc adjustments have to be made. The validity of many of these adjustments cannot be assessed by the normal scientific review process and, in the end, the well model cannot be defended.... studies involving a well are best handled using the more detailed MOTIF numerical model, outside of the SYVAC framework. [Comment 735, Source Document ph2gov001, Page geo6]

none of the cases considered seem to have tested the analytical well model.... Therefore, the performance of the analytical well model featured prominently in GEONET has not been demonstrated by thorough and objective checks. [Comment 738, Source Document ph2gov001, Page geo7]

Section 7.4.2 describes the adjustments made to the GEONET model, where the geosphere is represented by a network of 1D stream tubes, in order to account for the 3D effects of convergent flow and transport towards a well.... It is impossible to assess the technical validity of these adjustments because they are not established on scientific principles. [Comment 740, Source Document ph2gov001, Page geo8]

The authors provide no justification as to why a well model is included in the probabilistic SYVAC scenarios whereas other forms of human intrusion and human error (open borehole) are treated outside the SYVAC framework. They should provide a discussion of the probability of water supply well (s) being sited above the repository sometime in the future.... Despite the rational approach to scenario selection outlined in section 4.1. the "well" scenario implementation appears quite ad hoc. [Comment 775, Source Document ph2gov001, Page pos3]

The well depth in this second case study has been reduced from that described in the EIS. As a result, dose rate estimates obtained are not directly comparable to those in the EIS which were obtained from wells deeper on average and therefore closer to the vault. AECL's explanation for restricting the well depth is not very persuasive. If the deeper (200m) well cannot be modeled, this would suggest that the analytical well model in GEONET is inadequate. [Comment 820, Source Document ph2gov015, Page 01]

OPG RESPONSE

Implementation of the well model in GEONET is confounded by site specific hydrogeologic conditions, specific well demands and well depths. Change in any of these parameters may require a re-assembly of the GEONET 1-dimensional streamtube network, which is otherwise fixed in space and time. This approach to well simulation will not be adopted in future geosphere performance assessments.

7.03.04.03 Safety Assessment - Postclosure - Geosphere - Data Usage PARTICIPANT COMMENTS

Atomic Energy Control Board

AECL has never published a detailed report that integrates the data and information collected for the URL site and the Whiteshell Research Area (WRA), and then justifies the assumptions, structure and parameterization of the geosphere models based on that data. [Comment 568, Source Document gov002, Page 22, Section A.6.2]

there is no discussion of how the information collected during the underground characterization stage will be incorporated into an overall safety assessment of the site (Siting PRD, p. 213). [Comment 691, Source Document gov002, Page 79, Section E.2.1]

Northwatch (Richardson)

AECL describes in considerable detail the work conducted at several geologic investigation sites ... Unfortunately there does not appear to be much by way of description of how the various site-specific conceptual models were derived from these data and how useful those models then proved in iteratively predicting the results of future work. [Comment 1514, Source Document ph2pub009, Page 07, Section 2]

Description is given ... of how techniques exist to enable features such as fractures, high and low permeability zones and other features of importance in safety assessment modelling to be delineated, but there is no discussion of the limits in application of details of these features to the development of a site-specific conceptual model. [Comment 1515, Source Document ph2pub009, Page 07, Section 2]

Scientific Review Group

AECL has failed to show how field data for flow systems in fractured rock can be transformed into model input; this essential step may be difficult for the highly heterogeneous systems with large parameter uncertainty. [Comment 384, Source Document tec004, Page 057, Section 6.3.1]

AECL has not shown how additional field observations would translate into improved models or model input data. [Comment 443, Source Document tec004, Page 080, Section 6.6.3]

No information has been provided to show how the two most important parameters in the geosphere model (determined from AECL analysis), tortuosity and the groundwater velocity scaling factor, will be measured from field observations and linked to probability functions. [Comment 445, Source Document tec004, Page 080, Section 6.6.3]

Figure 6-22 shows an example of a multiple packer casing system within a 1200 m long borehole (URL-12). "... seventeen different intervals representing different degrees of fracturing on different lithological units are isolated within this borehole for hydrogeological monitoring and testing and for hydrogeological sampling." It is not clear how these data relate to the conceptual geosphere model comprising horizontal fracture zones (R-Geosphere, Figure 5.3.3., p.110, and associated text). [Comment 10, Source Document tec004, Page 107, Section A-2.1.4]

According to this document "AECL recently began integrating all the information obtained from grid area investigations of the Whiteshell Research Area since 1985 ... to develop and calibrate a large scale groundwater flow model of the research area." (R-Siting 1994: p.177). This information is not integrated into the geosphere model. [Comment 12, Source Document tec004, Page 107, Section A-2.1.4]

much of the geotechnical information from URL and other AECL Research Areas was not used in the development of R-Geosphere and R-Siting, and some of it, such as variations of fluid salinity (R-Siting 1994: Figure 6-13), contradicts fundamental aspects of the conceptual model for the geosphere which deals with groundwaters of uniform salinity (R-Geosphere 1994: GEONET).... the model should be based upon, and compatible with, information acquired at the URL and the rest of the WRA, but rather is based on a much oversimplified model of URL. [Comment 14, Source Document tec004, Page 108, Section A-2.1.4]

The description of site evaluation methods does not convincingly show how information gathered through site investigations will be used to develop a regional groundwater flow and solute transport model that could be used to locate and design a vault, to assess the environmental impacts of alternative vault locations and facility designs, or to assess the long-term safety of these alternatives There is no quantitative information about how laboratory and field data will be translated into groundwater flow and transport model parameters.... Nor does AECL seem to possess a sampling strategy that would help maximize, and assess quantitatively (say, by means of geostatistics), the reliability of its model input data.... [Comment 18, Source Document tec004, Page 109, Section A-2.2.1]

R-Geosphere does not give due consideration to the vast body of geological, geophysical, geochemical, and hydrogeological information concerning rock properties and in situ conditions in plutonic rocks that AECL and other organizations have documented in the WRA, and elsewhere in the Canadian Shield; and moreover, some of this information is incompatible with assumptions that have been adopted in R-Geosphere with respect to the Geosphere Model. The document does not refer to, or accommodate, some of the important information that is available from drill logs from the URL and the WRA, or from the other plutons on which AECL has conducted field studies, such as the Eye Dashwa Lakes pluton and the East Bull Lake pluton (R-Siting 1994). For example, mixing of groundwaters external to the Lac du Bonnet batholith with granitic groundwaters indigenous to the batholith (R-Geosphere 1994: Appendix A1, p.320) is inconsistent with the zero flow boundary conditions of the Geosphere Model [Comment 236, Source Document tec004, Page 215, Section G-3.1.3]

The document does not demonstrate any methodology for the translation of realistic field and laboratory data into parameters suitable for reliable numerical analysis (by means of models such as MOTIF) of postclosure groundwater flow and contaminant transport at a site comparable to the WRA. The document fails to demonstrate, or even to address, the questions: (i.) how properly to assign meaningful bulk parameters (mainly intrinsic permeability, effective porosity and retardation coefficient) to large masses of rock on the basis of smaller-scale, spatially variable test results; (ii.) how to evaluate the uncertainty associated with such parameters; (iii.) how to assess the extent to which such bulk parameters may mask rapid transport along preferential flow channels within the rock mass; and (iv.) how to analyze the uncertainty in travel times and solute concentrations caused by such masking [Comment 238, Source Document tec004, Page 217, Section G-3.1.6]

OPG RESPONSE

The issues raised in this comment category speak to the development of a conceptual model and the transfer of the conceptual model into a technically defensible mathematical realisation. These comments are consistent with an independent review of Geosphere PA methodologies conducted by the Deep Geologic Repository Technology Program (DGRTP) (Novakowski, 2000). Conceptual model development, which includes the methodology by which multi-disciplinary site characterisation data is combined to develop an internally consistent understanding of a fractured groundwater flow system, is a principle goal of the DGRTP. Geoscience work program activities undertaken in this regard are described in 7.03.04.01.

References

K.S. Novakowski. 2000. A review of geosphere performance assessment methodologies. Ontario

Power Generation report 06819-REP-01300-10008-R0.

7.03.04.04 Safety Assessment - Postclosure - Geosphere - Parameters

7.03.04.04.01 Safety Assessment - Postclosure - Geosphere - Parameters -General

PARTICIPANT COMMENTS

Atomic Energy Control Board

The transfer of geosphere parameter values from one location to an adjacent area without data confirmation is questionable. However, AECL does not provide evidence and reasoned arguments to support the contention that the selected parameter values are even appropriate for the intensively studied area around the URL. [Comment 559, Source Document gov002, Page 15, Section A.2.1(ii)]

OPG RESPONSE

This issue speaks to the development of the conceptual groundwater flow system model. This involves justification of the spatial and temporal flow system properties, parameter up-scaling and boundary conditions. The importance of conceptual model development is recognized in articulating the case for geosphere performance assessment. Deep Geologic Repository Technology Program activities taken in this regard are described in 7.03.04.01 (233).
7.03.04.04.02 Safety Assessment - Postclosure - Geosphere - Parameters -Sorption

PARTICIPANT COMMENTS

Atomic Energy Control Board

AECL does not provide adequate justification that a redox switch can be used to approximate actinide speciation (and hence actinide Kd) as a function of solution pH and redox (Geosphere PRD, p. 404). Under certain chemical conditions, some radionuclides can be present in solution as more than one species. [Comment 640, Source Document gov002, Page 58, Section C.3.2(i)]

The effects of dissolved organic complexes on radionuclide transport have not been adequately evaluated (Geosphere PRD, p. 339). To assume that the lack of specific data on radionuclide complexation can be compensated for by assuming that such effects fall within the range of uncertainty in the sorption data base is non-conservative. The reason for this is that reactive radionuclides could become more mobile in the presence of dissolved organic complexes. [Comment 642, Source Document gov002, Page 58, Section C.3.2(iii)]

the retardation coefficients in GEONET are calculated with a fitted equation containing 10 coefficients. This approach has not been justified, and the Kd values calculated in GEONET were not tabulated (Geosphere PRD, p. 207). The Kd values are important intermediate results, and they should be presented to allow reviewers to make comparisons with field and laboratory data. Furthermore, the validity of normalizing Kd values to porosity (Geosphere PRD, p. 208) has not been demonstrated (for example, see Geosphere PRD, p. 336). [Comment 644, Source Document gov002, Page 59, Section C.3.3(ii)]

OPG RESPONSE

In the model, the Kd data are described by an equation with 6 parameters that account for the dependence of Kd on TDS and nuclide concentration, 3 parameters that allow for uncertainties in the chemical conditions and nuclide concentration, and one parameter for the mineral density (Ticknor and Vandergraaf 1996). This format gives the analyst a fair amount of flexibility in treating the available Kd data. However, with the information available at the time of the EIS, most nuclides and minerals were treated very simply, i..e, most parameter were simply set to zero.

As noted, only retardation factors are needed and calculated for GEONET. It is acknowledged that Kd values are important intermediate results and should have been presented in the EIS. However, calculated median Kd values were compared to those from other programs in a supporting technical document (Vandergraaf and Ticknor 1994).

Vandergraaf and Ticknor (1994) note that most Kd measurements are made on crushed materials rather than intact rock. They further devise a method for converting these measured Kd values to Kd values appropriate for intact rock. The approach seems reasonable and is further discussed in Vandergraaf (1997). However, because of the importance of Kd values of the EIS assessment, the validity of this approach should be demonstrated by comparing the so-calculated Kd values with those obtained for intact rock in field studies or laboratory experiments on large blocks. OPG is currently funding work to measure apparent diffusivities (from which Kd values can be derived) in field experiments.

OPG agrees that the effect of dissolved organic complexes on radionuclide transport and solubilities have not been adequately addressed. At the same time, this is acknowledged in the EIS, as noted above, by use of wide distribution functions to describe the nuclide Kd in the geosphere.

References

Davison, C.C., T. Chan, A. Brown, M. Gascoyne, D.C. Kamineni, G.S. Lodha, T.W. Melnyk, B.W. Nakka, P.A. O'Connor, D.U. Ophori, N.W. Scheier, N.M. Soonawala, F.W. Stanchell, D.R. Stevenson, G.A. Thorne, T.T. Vandergraaf, P. Vilks, and S.H. Whitaker. 1994. The Disposal of Canada's Nuclear Fuel Waste: The Geosphere Model for Postclosure Assessment. Atomic Energy of Canada Limited Report AECL-10719.

Ticknor, K.V. and Vandergraaf, T.T. 1996. A Revised Compilation of Sorption Coefficients for Use in Geosphere Models in Performance Assessments of Used Fuel Disposal in Granitic Environments. Atomic Energy of Canada Limited Report AECL-11343.

Ticknor. K.V. and T.T. Vandergraaf. 1997. The treatment of sorption and retardation in the assessment of geological barriers to contaminant transport. Atomic Energy of Canada Limited Report AECL-11697.

Vandergraaf, T.T. And K.V. Ticknor. 1994. A compilation and evaluation of sorption coefficients used in the geosphere model of SYVAC for the 1990 assessments of the Whiteshell Research Area. Atomic Energy of Canada Limited Report AECL-10546.

Vandergraaf, T.T. 1997. The sorptive capacity of sparsely and moderately fractured rock. Atomic Energy of Canada Limited Report TR-752.

7.03.04.04.03 Safety Assessment - Postclosure - Geosphere - Parameters -Groundwater Residence Time

PARTICIPANT COMMENTS

Atomic Energy Control Board

There are no radiogenic isotopic data presented that support estimated groundwater residence times of 1,000,000 years (Geosphere PRD, p. 182). [Comment 646, Source Document gov002, Page 60, Section C.3.4(iii)]

OPG RESPONSE

Radiogenic isotopic data to support estimates of groundwater residence times in excess of 1,000,000 years were not reported in R-Geosphere. The context for the noted text R-Geosphere p. 182) was that given knowledge of the Whiteshell Research Area (WRA) flow system properties and stable isotope systematics it could be reasoned that residence times were on the order of 1,000,000 years below 500 m. Although preliminary, attempts to corroborate this assertion were made through comparison of hydrogeochemical evidence (i.e. elemental, 2-H,18-O) with 3-dimensional numerical flow simulations. The comparison indicated similar trends in estimated groundwater residence times. It is evident, however, that a more rigorous statement of the conceptual flow system model and description of the numerical realisations (i.e. relevant hydrogeochemical processes and mechanism; spatial/temporal boundary conditions) would have aided confidence in residence time assertions.

Gascoyne (2000) provides a compendium and integrated interpretation of WRA hydrogeochemistry data collected during the period 1980 to 1995. This report discusses the geochemical evolution of WRA groundwater's in terms of elemental compositions, Eh-pH, controls and environmental isotopes. Possible sources of the salinity within transmissive fracture zones and the intact rock matrix are discussed. These include long-term rock water interaction, residual hydrothermal fluids, soluble salts at grain boundaries and intrusion of Paleozoic marine waters. Reasoned hydrogeochemical arguments are put forth for an ancient marine source, either a basinal sedimentary brine or evaporite. It is evident that groundwater below 500 m in the WRA are saline, reducing and old, suggestive of stagnant groundwater flow conditions over periods of time considered relevant to repository safety.

References

Gascoyne, M. 2000. Hydrogeochemistry of the Whiteshell Research Area. Prepared by Gascoyne GeoProjects Inc. for Ontario Power Generation. Ontario Power Generation, Nuclear Waste Management Division Report 06819-REP-01200-10033-R00. Toronto, Ontario.

7.03.04.04.04 Safety Assessment - Postclosure - Geosphere - Parameters -Hydraulic Properties

PARTICIPANT COMMENTS

Canadian Geoscience Council

We would prefer to see at least two orders of magnitude variation in fracture thickness built into the modeling. [Comment 1061, Source Document tec002, Page 23, Section 4.1.2]

This tracer testing was inadequate for identifying the range of solute velocities and transmissivities in the fracture zone--even to within two or three orders of magnitude!... We suggest that a goal be to provide a probability density function of velocity (or of effective fracture thickness or of hydraulic conductivity). [Comment 1064, Source Document tec002, Page 24, Section 4.1.2]

Joint Committee of the Canadian Academy of Engineering and the Royal Society of Canada

confirmation of the range of solute velocities and transmissivities within a specific fracture zone were attempted by AECL tracer tests. These tests were inadequate for identifying the range of velocities and transmissivities to within two or three orders of magnitude (Ref. 15,p.24). [Comment 1161, Source Document ph2tec007, Page 08]

AECL ... provides only a modest amount of direct measurement of flow along fractures (use of impeller flow meters and pressure--flow measuring devices). Little is said about how the effects of damage from drilling are removed from the results of flow measurements or the precision of the measurements of fracture permeability.... Few permeability measurements are recorded in the reports reviewed and, given the great variability in individual fractures, large bodies of data would be required to infer average properties over large rock volumes such as those associated with vaults. [Comment 1147, Source Document tec003, Page w05, Section 5.2]

tracer tests and pressure transient tests ... can be used to infer average permeability and transport properties over larger volumes of rock between boreholes. AECL reports a limited amount of data of these types. [Comment 1148, Source Document tec003, Page w06, Section 5.2]

Natural Resources Canada

Uncertainty in tortuosity is modeled using a triangular probability density function (pdf) with minimum, maximum and mode of 2, 8 and 3, respectively (p.600). The sensitivity reported in section E.7 (p.597) considers different maxima and modes but the minimum value is never less than 2 (p.606). Some justification must be provided for this choice of minimum since tortuosities in fractured geological media may be closer to 1. [Comment 779, Source Document ph2gov001, Page pos4]

OPG RESPONSE

It is recognized that the development of a conceptual model for the flow domain is an important element in geosphere performance assessment. Development of the conceptual model provides a basis for the integration of multi-disciplinary field data into an internally consistent understanding of the flow system and inherent uncertainties. The process through which the conceptual model is derived allows rationalization of flow system (flow/transport/boundary condition) parameter uncertainty and spatial variability, which improves development of performance assessment modelling strategies. This is a particular problem in parameter up-scaling, flow system abstraction and dimensionality that may influence performance assessment outcomes. In this regard, the Deep Geologic Repository Technology Program (DGRTP) has focused efforts on improved conceptual model development, which include:

1) Development of revised hydraulic testing strategies and interpretative methods to better assess/estimate accuracy and precision;

2) Creation of the Moderately Fracture Rock Modelling Task Force to assess the limitations and capabilities of alternative geosphere

modelling techniques and conceptualizations;

3) The application of visualisation methods (i.e. VULCAN, GoCad) to improve field data integration, interpretation and communication;

4) The development of geostatistical approaches for quantitative analyses of spatially variable geologic/hydrogeologic data set;

5) The completion of a 3-dimensional Regional Flow System Analysis that will illustrate the sensitivity of permeability distributions and, gravity and

density gradients on groundwater flow paths and residence times relevant to repository safety;

6) The evaluation of Anomalous Hydraulic Heads and implication for existence of large domains of low permeability granitic rock

6) Continued flow system site characterisation and conceptualisation studies as part of the Moderately Fracture Rock Experiment; and

7) Continued research into transport parameter critical to mass transport in crystalline rock (i.e. Insitu Diffusion Experiment).

These work program activities are focused on improving presentation and integration of site characterisation data that underlie and support performance assessment (i.e. methods to evaluate/illustrate sensitivity of prediction to conceptual flow/transport model uncertainty).

In respect to specific comments, a revised interpretation of the WRA groundwater flow system is presented by Stevenson (1996). The conceptual model provides a more thorough explanation of permeability distributions and spatial correlation within the Lac du Bonnet batholith. A revised 3-dimensional numerical model of the WRA flow system based on this conceptualization is described by Ophori (1996). This revised model considered both the effect of gravity and density gradients on groundwater residence times and pathways. In conducting the modelling, sensitivity analyses were conducted on various WRA flow system realisations.

With respect to mass transport in sparsely fractured rock (SFR), the DGRTP has undertaken the Insitu Diffusion Experiment (Vilks, 2000). This is a multi-phase program intent on improving the understanding of pore water diffusivities in SFR. The experiment involves a series of parallel laboratory and in-situ Underground Research Laboratory experiments designed to yield comparative estimates of effective diffusivities. The experiment, among other goals, will examine issues of measurement scale dependence, porosity, pore geometry, tracer behavior and stress relief on uncertainty in estimated diffusivities. The experiment is scheduled for completion in 2003.

References

Ophori (1996)

Stevenson, D.R. et al. 1996. A revised conceptual model of a crystalline rock environment, Whiteshell Research Areas, Southeastern Manitoba, Canada. AECL-11331/COG-95-271.

Vilks, P., J.J. Cramer1, T.W. Melnyk, F.W. Stanchell, N.H. Miller and H.G. Miller. 1999. In-situ diffusion in granite: phase I final report. Prepared by Atomic Energy of Canada Limited and 1Geological Survey of Norway (NGU) for Ontario Power Generation. Ontario Power Generation, Nuclear Waste Management Division Report 06819-REP-01200-0087-R00. Toronto, Ontario.

7.03.04.04.05 Safety Assessment - Postclosure - Geosphere - Parameters - Well Depth

PARTICIPANT COMMENTS

Canadian Coalition for Ecology, Ethics and Religion

The in-room emplacement study limits well depth to 100m whereas the EIS case modelled for well depth of 200m. Dose rate dependence on time of travel to the well means much higher dose would be predicted to occur for 200m well than for 100m well ... For the 100m well, maximum total dose rates from selected radionuclides exceeded the dose rate associated with the regulation for all time frames beyond just over 100 years for simulations on moderate scenarios. Therefore, for the in-room emplacement case, the safety of the designs for 200m well is very much in question. [Comment 1868, Source Document ph3pub160, Page 6]

OPG RESPONSE

The characteristics of the well scenario will depend on site specific hydrogeologic properties, repository positioning and input into the geosphere. In developing a well scenario consideration of existing groundwater resource development, groundwater quality and quantity must be realistically taken into account. This should not, however, preclude the ability to conduct 'what-if' type scenarios that may position a water supply well in plausible and less favourable positions. With regard to the EIS (in-floor) and SCS (in-room) case studies, in the latter the discussion to limit well depths to 100 m was made based on time constraints and the knowledge that for simulation of well depths at 200m that the GEONET representation of sub-surface transport pathways required modification. These difficulties were noted in Stanchell et al. (1996) and Wikjord et al. (1996).

The Deep Geologic Repository Technology program is currently exploring the application of alternative and complimentary modelling approaches that would avoid the difficulties cited above. This includes pilot-projects which will test the utility of innovative mathematical performance and safety assessment codes that remain faithful to geosphere property distributions and geometry and thus provide increased flexibility for application (Therrien and Sudicky, 1996; VanderKwaak, 1999). This would include consistent application for water supply well release scenarios of various depth, pumping rate and variable sub-surface properties.

References

Stanchell, F.W., C.C. Davison, T.W. Melnyk, N.W. Scheier and T. Chan. 1996. The disposal of Canada's nuclear fuel waste: A study of postclosure safety of in-room emplacement of used CANDU fuel in copper containers in permeable plutonic rock. Volume 3: Geosphere Model. Atomic Energy of Canada Limited Report, AECL-11494-3, COG-95-552-3.

Therrien, R., and E.A. Sudicky. 1996. Three-dimensional analysis of variably saturated flow and solute transport in discretely fractured porous media. Journal of Contaminant Hydrology, 23, 1-44.

VanderKwaak, J.E. 1999. Numerical simulation of flow and chemical transport in integrated surfacesubsurface hydrologic systems. Ph.D.

Thesis, Department of Earth Sciences, University of Waterloo, Waterloo, Ontario, Canada.

Wikjord, A.G., P. Baumgartner, L.H. Johnson, F.W. Stanchell, R. Zach and B.E. Goodwin. 1996. The disposal of Canada's nuclear fuel waste: a study of post-closure safety of in-room emplacement of used CANDU fuel in copper containers on permeable plutonic rock volume 1: summary. Atomic Energy of Canada Limited. Report No. AECL-11494.

7.03.04.05 Safety Assessment - Postclosure - Geosphere - Research PARTICIPANT COMMENTS

Canadian Geoscience Council

New developments in understanding of non-linear and complex systems make it very likely that there will be new models (not just new computer models, but new conceptual models) for the longer term predictions. Those reponsible for implementing the disposal plan should be aware of these emerging models, and should encourage/finance their development as alternatives to the current generation of hydrologic models. [Comment 1054, Source Document tec002, Page 21, Section 3.4.3]

Canada has entered an era of major budgetary restraint.... The infrastructure of the geological sciences has already been, or shortly will be, eroded to the point where it will be difficult to collect data required for the site selection. We urge attention to this problem. [Comment 1080, Source Document tec002, Page 29, Section 5.3]

the committee recommends that: ... ongoing research and modeling be flexible, evolving, and not locked into existing codes for geosphere response to the repository. [Comment 1022, Source Document tec002, Page ii, Section ES]

Natural Resources Canada

Given the apparent importance of tortuosity in the SYVAC simulations, it is cause for consternation that its values are based on such small and unrepresentative data set.... there should be further research into tortuosity and diffusive transport in sparsely fractured rock. This research should seek to establish the true range of in-situ tortuosities near an excavation in the lower rock zone and to clarify the relationship between tortuosities measured at the core scale and values assigned to larger volumes of rock in the MOTIF and GEONET models. [Comment 907, Source Document ph2gov001, Page pos4]

OECD/NEA Review Group

The issue of colloidal transport of radionuclides was not a feature of the Reference Case, as the sparsely fractured rock and the buffer act as effective filters for any colloids generated in the near-field. The Group agreed that this approach was acceptable for the Reference Case. However, this may not be the case for other sites where more fractured rock may be present, and continued study of natural groundwater colloids as well as those generated within the engineered barriers is to be encouraged. [Comment 1217, Source Document tec001, Page 10, Section 3.2.2]

The EDZ is judged by AECL to have no impact in the sparsely fractured rock, but further work needs to be done on its behaviour in moderately fractured rock if the geological environment at a repository site is less favourable than at the URL (see comments in Chapter 3). [Comment 1252, Source Document tec001, Page 18, Section 5.2]

OPG RESPONSE

The Deep Geologic Repository Technology Program (DGRTP) recognizes the need for continued geoscience research and model development that will further aid development of the repository safety case. In this regard, the DGRTP geoscience work program is focused on several key research areas that include:

1) Development and maintenance of numerical PA tools;

2) Development of visualisation and electronic database information system to aid flow/transport system conceptualization;

- 3) Advancing knowledge of mass transport in porous-fractured media; and
- 4) Creation of a University Liaison Program.

These programs, among others, are designed to addressed technical comments raised during the federal hearing and to preserve site characterisation skills unique to fractured Shield settings. As part of performance assessment, the application of alternative numerical flow and transports models is being pursued in the Moderately Fracture Rock Experiment and Regional Groundwater Flow System Analysis. These alternatives models focus on the simulation of complex flow system geometries and boundary conditions which imparts flexibility for future application. The application of electronic data processing (e.g. GIS) and visualisation methods (VULCAN, GoCad) are being explored to aid integration of multi-disciplinary data sets for flow system conceptualisation. Research into advectivedispersive-diffusive mass transport is continuing as part of the Underground Research Laboratory based MFR and In-situ diffusion experiment. The latter experiment is intent on improving the knowledge of diffusive mass transport through sparsely fracture granitic rock through a series of comparative field and laboratory experiments (i.e. spatial variability and scale dependency of porewater diffusivities)(Vilks et al, 1999). Numerical insight studies of mass transport have also been completed to study the effects of repository and flow system geometry on repository performance . This includes Chan et. al. (1999) which examine the influence of an Excavation Damage Zone (EDZ) on mass transport. Finally a University liaison project has been created in the geoscience program to foster graduate and post-graduate level research and development on topics most relevant to the used fuel repository Safety Case.

A summary of DGRTP geoscience activities and progress can be found in Gierszewski et al. (2001).

References

Chan, T., M. Kolar, P.A. O'Connor, N.W. Scheier and F.W. Stanchell. 1999. Finite-element sensitivity analysis of effects of an excavation damage zone on 129I transport from a used CANDU fuel waste disposal repository. Atomic Energy of Canada Limited for Ontario Hydro. Ontario Hydro Nuclear Waste Management Division Report No: 06819-REP-01200-0022-R00.

Gierszewski, P., S.B. Russell, F. Garisto, M.R. Jensen, T.F. Kempe, P. Maak and G.R. Simmons. 2001. Deep geologic repository technology program - annual report 2000. Ontario Power Generation, Nuclear Waste Management Division Report 06819-REP-01200-10055-R00. Toronto, Ontario.

Vilks, P., J.J. Cramer1, T.W. Melnyk, F.W. Stanchell, N.H. Miller and H.G. Miller. 1999. In-situ diffusion in granite: phase I final report. Prepared by Atomic Energy of Canada Limited and 1Geological Survey of Norway (NGU) for Ontario Power Generation. Ontario Power Generation, Nuclear Waste Management Division Report 06819-REP-01200-0087-R00. Toronto, Ontario.

7.03.04.06 Safety Assessment - Postclosure - Geosphere - Scenarios PARTICIPANT COMMENTS

Canadian Geoscience Council

We did not find the discussion of [the occurrence of possible long-term changes or catastrophic or unusual events] to be very deep or satisfactory in light of modern discoveries about possible rate of climate change, difficulties in predicting rare but large earthquakes, and the difficulties with long-term forecasting discussed above. [Comment 1047, Source Document tec002, Page 17, Section 3.3.1]

Scientific Review Group

the key scenarios that remain to be investigated are those involving the impact of the hydraulic and hydrogeologic parameters on radionuclide travel time and dose. These parameters should at the least have included the flow/transport boundary conditions, the vault location (depth as well as location within the regional flow system), the hydraulic conductivity distribution (varied systematically or at random), and the distribution of fracture zones. The analysis should also have included the influence of salinity as well as the vault heat input on the density of the groundwater in a 3D coupled flow/transport model (MOTIF). Comprehensive sensitivity analyses should have been conducted on these parameters. From among the results, a few critical scenarios could then have been selected for a complete SYVAC analysis using all 788 parameters if desired. [Comment 523, Source Document tec004, Page 171, Section E-2.1.4]

OPG RESPONSE

The issue of dimensionality and inclusion of processes and mechanisms potentially influencing radionuclide migration in the geosphere is an important aspect of performance assessment. In the GEONET approach adopted by AECL the geosphere was assumed steady state with contemporary boundary conditions governing. Various long-term geosphere scenarios, while not explicit or perhaps as transparent as reviewers would have wished, were to have been captured through assignment of Probability Density Functions for geosphere model input parameters under the System Variability Analysis Code (SYVAC) framework. Technical comments submitted on the EIS and SCS have been reviewed with key issues surrounding presentation of the Geosphere Performance Assessment identified (Jensen and Goodwin, 1999). In addition, an independent review of geosphere performance assessment strategies that generated 14 recommendations was undertaken by the Deep Geologic Repository Technology Program (Novakowski, 2000).

Current work activities in the Deep Geologic Repository Technology Program (DGRTP) involve the improvement and testing of alternative 3-dimensional modelling techniques for geosphere (and repository) performance assessment. Such techniques, which take advantage of increased computing power, robust sparse matrix solvers for unstructured 3-dimensional meshes, fully implicit Control Volume Finite Element algorithms, flux limiters to control numerical dispersion on coarse meshes and adaptive time-stepping procedures are being explored to compliment existing PA methods. In addition to these activities, OPG is an industrial partner in the Federal Government's Canadian Water Network initiative, which will foster the development and demonstration of alternative PA modelling strategies at universities across Canada. The intent of this work is to evaluate numerical methods that may offer increased flexibility in future PA through remaining faithful to 3-dimensional geosphere geometry (i.e. hydraulic conductivity distributions) and, transient flow and transport boundary conditions. A description of DGRTP geoscience work program activities may be found in Gierszewski et al. (2001).

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7.03.04.07 Safety Assessment - Postclosure - Geosphere - Waste Exclusion Zone

PARTICIPANT COMMENTS

Atomic Energy Control Board

the presence of a network of sparse, interconnected, small fractures across the waste exclusion zone could significantly decrease the groundwater transit time as a result of both increased permeability and decreased effective flow porosity. Neither the permeability nor the effective flow porosity of the waste exclusion zone are varied in the probabilistic simulations.... Differential expansion of the rock and porewater in the waste exclusion zone due to the thermal pulse from the waste could cause cracking of low permeability rock in the exclusion zone. AECL does not adequately assess potential scenarios whereby the presence of the repository could degrade the barrier effectiveness of the waste exclusion zone. [Comment 2158, Source Document gov002, Page 16, Section A.3.1]

Discussions about system performance for various minimum waste exclusion distances are misleading, because most of the vault is separated from Fracture Zone LD1 by much larger distances. [Comment 657, Source Document gov002, Page 67, Section C.7.3]

Hare, Driedger, Jennekens, Rogers, and Shemilt

Among the subjects of concern are ... the existence of [a sparsely fractured] rock mass between the vault and the nearest fracture zone [Comment 1404, Source Document phpub150, Page 4]

Scientific Review Group

The SRG questions the assumption that a 50-m waste exclusion zone of undisturbed or sparselyfractured rock will always exist and maintain its integrity throughout the lifetime of the repository. The SRG concern is based on a number of reasons. First, a volume of rock of sufficient size with the requisite uniformly low permeability has not been documented.... Second, excavation damage in combination with high stress concentrations in the rock adjacent to the vault may cause fracturing and thus compromise the integrity of the WEZ.... under the prevailing high differential rock stress regime, fracturing may occur in the rock webs between the boreholes and around individual rooms. The possibility of significant extension fractures developing in the plane of the repository, due to the stress concentrations induced by the excavation, should not be ignored.... Third, long-term changes in the stress fields due to thermo-mechanical or tectonic processes may induce future fracturing. Seals may not be fully reliable under these conditions. AECL has recognized that ... the performance of the seals over long time periods cannot be predicted (R-Barriers 1994: p.189). [Comment 369, Source Document tec004, Page 054, Section 6.3.1]

the validity of the assumption that transport through the sparsely-fractured rock surrounding the vault will always be diffusive depends entirely on the uniformly low permeability value assigned to the rock. This value is not supported by field or laboratory measurements. If fractures in this rock zone were locally continuous, or interconnected, or if existing fractures were to widen and to propagate in the future owing to alterations in the stress fields, the permeability would locally increase and advection could become important. Because of the very low permeability required for the WEZ, a single undetected or unsealed borehole could also change the diffusive character of contaminant transport. [Comment 372, Source Document tec004, Page 055, Section 6.3.1]

The SRG expects the sorption capacity of mineral surfaces in fractures of sparsely-fractured rock to be severely limited by the restricted surface area of fractures. As groundwater flow will be concentrated in the more open parts of the fractures (channels), the area available for sorption will be further limited. There is, to the knowledge of the SRG, no experimental evidence to indicate that the bulk sorptive capacity of sparsely-fractured rock is substantial. The effectiveness of the WEZ as a sorptive barrier for contaminants would depend on the WEZ being essentially unfractured and transport being purely diffusive through the pore space of the solid rock. If continuous fractures were present and transport were advection-dominated, the surface area available for sorption would be very small and the sorptive-barrier effect would also be small. [Comment 373, Source Document tec004, Page 055, Section 6.3.1]

neither calibration against pumping test data and the associated validation against URL excavation data, nor tracer tests, help define in any reliable way the hydraulic properties (intrinsic permeability, effective porosity or retardation coefficient) of the less permeable rocks surrounding these fracture zones. If the effective porosity in the sparsely fractured rock is much higher than assumed, and the intrinsic permeability is at least locally much higher than assumed, postclosure groundwater velocities and contaminant transport times through this zone may be much higher than predicted with MOTIF, and the notion of an effective waste exclusion zone may not be valid. In particular, the assertion that solute transport through the sparsely fractured rock (including the waste exclusion zone) is diffusion-dominated rather than advective-dominated may not be valid, and thus all transport calculations reported for the geosphere in the EIS and its supporting documents may be invalid. [Comment 239, Source Document tec004, Page 217, Section G-3.1.6]

The effect of stress changes in the host rock due to the vault excavation and other short-term or longterm factors has not been thoroughly investigated. The excavation of the vault will affect the stress field in the host rock, and will create stress concentrations, which might be amplified by earthquakes and other tectonic processes. Through-going fractures to the surface do develop from underground mining excavations.... The integrity of the sparsely fractured rock surrounding the vault (the waste exclusion zone), which is the critical barrier for the containment of the contaminants, depends upon the mechanical stability of the vault. As discussed in the SRG Evaluation of R-Facility (Appendix C of this report), high in situ deviatoric stresses and stress concentrations inherent in the reference disposal system might lead to fracturing that would breach this critical barrier. AECL has not addressed this critical issue in the development of the Geosphere Model [Comment 243, Source Document tec004, Page 219, Section G-3.2.4]

OPG RESPONSE

Within the Environmental Impact Statement (EIS) realisation of the used fuel repository system, the Waste Exclusion Zone (WEZ) enclosing the repository created a significant diffusive barrier to radionuclide migration. The WEZ as envisioned in the EIS was comprised of a large domain (approx. 50 m) of sparsely fractured or intact granitic rock with a permeability of 10-19 m2 or less. Geoscience issues surrounding the role of the WEZ on repository safety focus on the ability to characterise large domains of sparsely fractured rock and the assessment of long-term WEZ integrity. While these issues remain valid and continue to be examined as part of the Deep Geologic Repository Technology Program (DGRTP), they are not necessarily germane to the safety of the repository concept. As illustrated by the Second Case Study (SCS), a modified system of repository-engineered barriers within a more permeable geosphere without a WEZ was demonstrated to satisfy regulatory criteria. Nonetheless, relevant DGRTP activities related to WEZ characterization and longevity focus on physical and chemical hydrogeologic properties, sensitivity analyses for radionuclide transport, fracture propagation and predicted thermal-hydraulic-mechanical responses.

Geoscience research at the Underground Research Laboratory continues to provide evidence for the existence of large domains of sparsely fractured rock within the Lac du Bonnet batholith. The Deep Probe Hole, which extends 736 m from the Underground Research Laboratory 420 level, intersected a single healed fracture along its length (Everitt and Woodcock, 2000). A review and case history of WRA hydrogeochemistry data provide evidence of unique pore water chemistries indicative of basinal

brines or marine water ingress (Gascoyne, 2000). Anomalous hydraulic heads observed in deep multilevel casing systems may also be indicative of large domains of sparsely fractured rock as discussed by (Chan et. Al. 1998). Numerical insight modelling in collaborative international program such as DECOVALEX III are examining the development of coupled Thermal-Hydraulic-Mechanical codes necessary to understand rock stress and property response to repository excavation and heating. Diffusive transport in sparsely fracture rock continues to be investigated through the In-situ Diffusion Experiment (Vilks, 2000). This experiment is designed to advance the understanding of scale dependency and spatial variability of diffusivities within sparsely fractured rock. A more complete description of DGRTP work program activities may be found in Gierszewski et al. (2001).

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7.03.05 Safety Assessment - Postclosure - Biosphere

7.03.05.01 Safety Assessment - Postclosure - Biosphere - Conceptualization PARTICIPANT COMMENTS

Canadian Coalition for Ecology, Ethics and Religion

the method of modelling the ecosystems and evaluating the impact on non-human biota has to be improved to respond to the dynamics, complexities and diversity which are orders of magnitude beyond the approach presented in the EIS and in-room emplacement cases. [Comment 1864, Source Document ph3pub160, Page 4]

Ecosystem Approach Group

I object to this list [of biosphere factors] because in the biosphere the factors related to living things interact with each other and here the interactions are not accounted for. Indeed, in Appendix C the living things are not included (which confirm that AECL does not know what the biosphere is). [Comment 2031, Source Document pub033, Page 05]

The biosphere is not limited to the portion of the earth inhabited by living organisms, as the glossary suggests. It includes the living organisms, together with their abiotic environment, together with the energy necessary for their reciprocal interactions. [Comment 2033, Source Document pub033, Page 05]

In their definition of biosphere (pg.493 [EIS]) it seems that no life exists in the atmosphere, in the surface water, in the shallow lake sediments. It also seems that the plants and animals do not interact within the biosphere through energy exchanges. [Comment 2037, Source Document pub033, Page 09]

Environment Canada

the issue of "spatial extent" is not addressed in the Biosphere Model. Both magnitude and extent of contamination/impact are important, even when impact is not expected in the near-field discharge zone. This spatial pattern would permit intuitive scaling of results when considering the consequences of higher source fluxes. [Comment 888, Source Document gov003, Page 33, Section 2.15]

Scientific Review Group

This arbitrarily restricted definition of the biosphere may limit the ability to take advantage of new knowledge and understanding of biological and biochemical reactions, and to assess, through the modelling procedures used, the influences that biological processes may have on the long-term movement of radionuclides [Comment 392, Source Document tec004, Page 059, Section 6.4.1]

A further dimension of the limited scope of biological processes and characteristics modelled by BIOTRAC is that the movement of radionuclides along the various pathways and through biosystems is considered, for modelling purposes, to be exclusively unidirectional. In this regard, three important assumptions stated by AECL are critical to the success of BIOTRAC (R-Biosphere 1994: pp.401-404). These are:

- that feedback of the effects of radionuclides on elements of or processes in the biosphere can be neglected and thus that the model is unidirectional;

- that processes governing radionuclide movement through the biosphere can be modelled using simple transfer coefficients;

- that the wide variety both of environmental behaviour of different chemical species of the same radionuclide and of different biochemical interactions can be accounted for by a range of parameter distributions....

important characteristics of the biosphere that could affect the movement of contaminants could be missed or misinterpreted by such simplifying assumptions.... the assumptions ... need to be critically re-appraised. [Comment 397, Source Document tec004, Page 064, Section 6.4.2]

The BIOTRAC model treats movement radionuclides through the biosphere as a purely physical process, ignoring the fact that the distinguishing feature of the biosphere is that it is alive and capable of responding and adapting to changes in the immediate environment.... Over the protracted time under consideration, the non-linear biologically-influenced processes could be significant. [Comment 399, Source Document tec004, Page 065, Section 6.4.2]

there is no clear coherent statement of a conceptual model that integrates current knowledge and understanding of ecological processes so as to relate various elements and sub-elements of the pathway simulation models and the exposure of non-human generic organisms to the overall problem of environmental impact. Without such an overall conceptual model that takes into account net energy flows and biological processes, the BIOTRAC calculations treat the biosphere as an assembly of mechanical processes, ignoring the fact that the biosphere is a living system in which the whole is more than, and different from, the sum of those component parts that can be separately modelled. A coherent comprehensive conceptual model of the biologically-related processes appears to be necessary if present estimates of rates and effects of radionuclide transfer processes are to be extrapolated to ten thousand years with confidence. It should include the best information on biomass distribution in various living and non-living compartments, the end points or boundaries of the system being modelled, and mass and energy flows via the various pathways. [Comment 400, Source Document tec004, Page 065, Section 6.4.2]

inflexibility of the unidirectional sub-models used to calculate transfers along the selected pathways.... The best approach to the problem appears to be to develop a comprehensive conceptual model of the dynamic ecological and biological processes [Comment 410, Source Document tec004, Page 067, Section 6.4.2]

BIOTRAC ... is not concerned with biological functions as they may be involved in interim storage, feedback, adaptation or internal behaviourial response which in turn could affect accumulation, diversion or short-cuts in pathways, or accelerated transfer of radionuclides. Nor is it concerned with the possible effects of contamination on the biosphere as a whole. [Comment 419, Source Document tec004, Page 069, Section 6.4.2]

The boundary for the biosphere appears to be the watershed occupied by the critical group (lake only). This is not sufficient for consideration of collective dose; it is also not sufficient for consideration of far-field impacts on non-human biota arising from long-range transport of contaminants (eg. via river) [Comment 159, Source Document tec004, Page 172, Section E-2.1.5]

nowhere has AECL addressed how the whole of the biosphere may be considerably more than the sum of its arbitrarily identified parts.... A conceptual model suitable as a basis for formulating the linked problems to be addressed through BIOTRAC should, as a start, bring together in a cohesive fashion the following:

- a catalogue of the contaminants likely to be delivered; of the receptors of concern or taken to be representative (and why); of the features, events, and processes that according to present knowledge are judged to be important in the selection of scenarios for transport and the pathways to be modelled; - description of the entry and exit endpoints for the transport being modelled; and

- the boundary conditions for human and non-human biota.

Such information, combined with best information of the biomass and its distribution in different environmental compartments, and of the mass and energy flows via soil water, surface water and atmosphere, would have allowed the various sub-pathways and impulse response function terms (R-Biosphere 1993: Section 2.6) of BIOTRAC to be placed along the expected pathways from the vault to the surface biosphere and to humans with more confidence than is given by the present scenarios. [Comment 256, Source Document tec004, Page 228, Section H-2.1] A further difficulty with the one-way linkage of processes simulated in the soil, surface water, and food chain sub-models is that the scenarios chosen are treated as if they are steady-rate, and that processes and interfaces will remain unchanged over the long time period.... This purely chemical approach may lead to a difficulty in modelling random or irregular events which could be important or decisive in the transport of radionuclides.... This kind of event may not be accounted for by BIOTRAC, because its structure cannot accommodate short-lived or irregularly periodic processes except at the input stage. (R-Biosphere 1993: p.19). [Comment 257, Source Document tec004, Page 229, Section H-2.1]

Biological actions to concentrate, accumulate, or disperse chemical elements or compounds are fundamental processes of all ecological systems, but are not explicitly recognized in the construction of the BIOTRAC sub-models.... The biological processes of biochemical speciation and fixation, production and release of biofilms, biochemical transport or accumulation at trophic interfaces in the food chain, genetic response to ionizing energy, etc. are not given attention. [Comment 264, Source Document tec004, Page 231, Section H-2.2]

The analysis, assessment and predictions made through BIOTRAC are handicapped by the absence of a clearly described comprehensive conceptual model or description of the characteristics and workings of the surface environment and biological systems which can be used as a basis for formulation of the overall problem addressed and as a reference or context into which the various steps and sub-models can be fitted. Without such a conceptual model the various parts of BIOTRAC appear to have developed in piecemeal and somewhat independent fashion; it has been difficult to retain overall perspective, with the result that the amount of detailed analysis (and thus the cost of modelling) varies considerably in different parts, without a clear view of the relative priorities of respective parts. [Comment 292, Source Document tec004, Page 237, Section H-3]

the time factor of biologically-affected movement of radionuclides, such as delays or acceleration of transport due to biological processes, is not considered; this is in contrast to the very slow transport characteristic of the vault and geosphere models [Comment 296, Source Document tec004, Page 238, Section H-3]

the processes of radionuclide transport are linear and unidirectional, with no feedback, transient storage, or spasmodic releases. [Comment 297, Source Document tec004, Page 238, Section H-3]

Overall, the BIOTRAC model gives little recognition or allowance for the fact that biological systems are almost infinitely complex and adaptable, especially over long periods of time and under influences, such as those likely from ionizing radiation and toxic chemicals, that are not likely to be lethal but which could possibly be adapted to. Inasmuch as it is the microbiological, invertebrate and non-vascular forms of life that are most adaptable to subtle changes in chemical or ionic conditions, and it is these levels of biological systems that control the vigour and sensitivity of ecosystems, it may be that limitation of analysis and assessment to the effects on higher plants, animals and humans in BIOTRAC will miss the fundamental long-term effects on the environment of radionuclides escaping from a waste disposal vault. [Comment 298, Source Document tec004, Page 238, Section H-3]

AECL has not addressed biomass attribution in the conceptual model (e.g. tonnes/hectare) in terms of the relative masses of animals, plants and microorganisms associated as parts of the biosphere.... This compromises the validity of any modelling claimed to reflect the biosphere at the selected site.... There has been no attempt to ascribe mass, volume, spatial location to the various components along the pathways from the vault to the surface biosphere, nor has there been any attempt to address the functional impact of the organisms in the subsurface or surface biosphere on the rate of transport and retention at various stages. [Comment 312, Source Document tec004, Page 244, Section I-2.6] If present estimates of rates and effects of radionuclide transfer processes are to be extrapolated, with confidence, to ten thousand years, a coherent comprehensive conceptual model of the biologically related processes is required. It should include the best information on biomass distribution in various living and non-living compartments, the end points or boundaries of the system being modelled, and mass and energy flows along the various pathways. [Comment 528, Source Document tec004a, Page 13, Section 2.6]

The BIOTRAC model treats the movement of radionuclides through the biosphere as a purely physical process ... Over the protracted time under consideration, non-linear biologically-influenced processes are most likely to be significant. [Comment 543, Source Document tec004a, Page 18, Section 3]

The assumption that the movement of radionuclides along the various pathways and through biosystems is considered, for modelling purposes, to be exclusively unidirectional, which remains in the new case study, is still a matter of concern. [Comment 544, Source Document tec004a, Page 18, Section 3]

OPG RESPONSE

In the context of postclosure assessment of used fuel disposal, the biosphere covers only the surface environment and does not include the vault and geosphere. This restricted biosphere definition focuses on those parts of the biosphere that are readily accessible to humans and other important target organisms that need protection (Davis et al. 1993, p. 11-13). The possible effects of microbes in the vault and geosphere are treated in Johnson et al. (1994) and Davison et al. (1994), respectively.

It should be emphasized that the scope and purpose of BIOTRAC, the biosphere model used in the EIS, was very limited - to calculate nuclide concentrations in the various environmental compartments resulting from used-fuel disposal in a geologic repository and to estimate radiological doses to humans and non-human biota from all credible exposure pathways. Because of the acknowledged difficulty in modelling the biosphere, empirical models and data are often used in BIOTRAC to determine the migration of nuclides through the environment (e.g., plant uptake of nuclides from soil). Consequently, many biosphere processes need not be modelled explicitly (e.g., transpiration) because these processes are implicitly accounted for in the empirical models. BIOTRAC is not very different from models developed elsewhere (Bergstrom et al. 1999; U.S. DOE 1999; CSA 1987) for calculating the consequence of nuclide releases to the environment. For these reasons, we believe that BIOTRAC is an appropriate tool for predicting exposure doses resulting from used-fuel disposal in a geologic repository.

In the EIS, only exposures to the most exposed individuals were calculated. Thus, the human exposure scenarios in the EIS involved a self-sufficient critical group living near the vicinity of the repository. The critical group grows food in contaminated soil and uses water from contaminated sources. For this reason, it was not necessary in the EIS to consider the surface water drainage system downstream of the discharge location of groundwater from the vault. Nuclides flushed to downstream lakes and rivers would be diluted by additional surface runoff and individuals living downstream of the discharge location would thus receive lower doses than members of the critical group.

Nevertheless, it is recognized that the EIS did not cover a sufficient range of human and biosphere characteristics of particular interest to some stakeholders. Consideration should be given, in future assessments, to calculating doses for a range of human and biosphere characteristics. Also, regulators may require the calculation of nuclide concentrations in the surface environments downstream of the vault location and exposure doses to critical groups living at these downstream locations. Such calculations, which are routinely carried out for uranium mining operations, would only be feasible after a repository site has been selected and the surface environment is defined. It is also recognized that the method of modelling the ecosystems and evaluating the impact on non-human biota has to be improved to better account for biosphere diversity.

BIOTRAC uses many simplifications. For example, radionuclide losses from the soil layer due to plant uptake are not accounted for in the model. In this way, recycling of radionuclides (e.g., use of compost material in gardens, animal waste on fields, etc.) is implicitly modelled. Because of these simplifications, nuclide transfers in BIOTRAC are mainly unidirectional - from areas of high nuclide concentrations to areas of lower concentrations.

Radiological and chemical exposures to humans and non-human biota resulting from used fuel disposal in a geologic repository are expected to be much smaller than the corresponding background exposures. Therefore, the radionuclides and chemical elements released from the vault are not likely to affect the evolution of the biosphere. Any potential effects from the vault would be far outweighed by natural variation in environmental and ecological conditions.

In the development of BIOTRAC, the question of environmental and ecological changes was evaluated (AECL, 1996). This led to the distinction between fluctuating and transitional processes. Fluctuating processes involve relatively rapid variation about some mean condition (e.g., seasonal temperature changes); transitional processes involve periodic or non-periodic changes such as continental glaciation. Fluctuating processes are considered in BIOTRAC through parameter variability (Davis et al. 1993). Thus, each simulation represents a slightly different biosphere.

In conclusion, it is expected that biosphere modelling methods will continue to evolve and there will be a greater variety to choose from by the time that assessments are carried out for a proposed disposal site. When the time comes, the most appropriate methods for the conditions at a proposed disposal site would be used.

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7.03.05.02 Safety Assessment - Postclosure - Biosphere - Models

7.03.05.02.01 Safety Assessment - Postclosure - Biosphere - Models - BIOTRAC PARTICIPANT COMMENTS

Ecosystem Approach Group

None of the assumptions made by AECL in formulating the model and setting the parameters are justified; AECL does not come even close to predict the effect of the foreseeable facility. BIOTRAC is not suitable nor satisfactory to describe nuclide behaviour in the biosphere; it underestimates doses to humans and the biota. [Comment 2040, Source Document pub033, Page 11]

Scientific Review Group

The BIOTRAC model does not appear suitable for exploring various hypotheses about radionuclide movement and environmental response, because a number of assumptions made in advance about relationships in the food chain, ground water movement in soil, steady-state processes, etc., which are based on current observations and short-term data may not be valid over ten thousand years. [Comment 403, Source Document tec004, Page 066, Section 6.4.2]

Although it can be applied to a variety of sites, BIOTRAC does not appear to be suitable for examining changing conditions at a given site, or for comparing alternative sites: in this context BIOTRAC is not a general-purpose model of movement of radionuclides in the environment.... the structure flowpaths or different environmental conditions cannot be examined without re-setting the model (R-Biosphere 1994: pp.292-295). [Comment 412, Source Document tec004, Page 067, Section 6.4.2]

Because each pathway in the BIOTRAC sub-models is fixed once calculations start, with the exception of some pre-organized switch parameters, it is not possible to explore variations in travel paths. This means, in effect, that changes in the natural environment or in source terms over ten thousand years cannot be accommodated, and thus BIOTRAC predictions are likely to be quite different from reality [Comment 418, Source Document tec004, Page 068, Section 6.4.2]

the SRG is concerned about possible misrepresentation of the capabilities of BIOTRAC. In particular, issue is taken with the AECL assertion the model makes "valid predictions over a period of about 10,000 years" (R-Biosphere 1994: p.397). This assertion is unacceptable for two reasons. First, because the complete model has not been and cannot be validated over a time period of 10,000 years ... Second, the model cannot take time-dependent changes in the environmental conditions into account, and furthermore, transport processes in the model are assumed to take place in a one-dimensional fashion without feed-back mechanism.... The SRG does not accept the argument that uncertainty in the model structure, the inability to represent transient processes, or the lack in model responsiveness to environmental changes, can be validly represented by assuming a wide range of the PDFs of the model parameters. [Comment 428, Source Document tec004, Page 073, Section 6.5.4]

The path of radionuclide transport followed by the successive calculations in each BIOTRAC submodel may not have sufficient flexibility to account for and predict changes in the biosphere and surface environment throughout time (10,000 years).... It appears that the inflexibility lies both with the structure of the BIOTRAC model, and with the process of selection of a limited range of fixed central scenarios that lead to a concept of invariate one-dimensional pathways (R-Biosphere 1993: p.14). [Comment 266, Source Document tec004, Page 232, Section H-2.3]

Nor, it would appear, could the one-dimensional, one-way construction be a means of exploring unexpected shortcuts, especially if biologically induced feedbacks and blockages could retard transport, divert it to new paths, or lead to accumulation of radionuclides or toxics. [Comment 267, Source Document tec004, Page 232, Section H-2.3]

if the BIOTRAC model is to be used ..., it should at least be able to examine a wide range of potential human situations and human-instigated activities that might affect the environment. It must also be modified so that it can accommodate variable rates with time, feedbacks, and multiple paths. [Comment 542, Source Document tec004a, Page 18, Section 3]

OPG RESPONSE

It is recognized that the biosphere around any site would likely change over the next 10,000 years, as a result of human activities or natural forces. Predicting a specific evolution is however difficult, e.g., there is still disagreement about the extent of global warming caused by human activities, and therefore any assumed biosphere evolution scenario could be challenged. The approach to this situation in the EIS was through two steps. First, by isolating the used fuel in a deep geologic repository, the fuel would be partially isolated from changes occurring on the surface. Second, the EIS biosphere model would examine a number of different but steady-state biospheres.

With respect to this latter point, the EIS biosphere model, in accord with international practices, assumes that the biosphere remains constant throughout the simulation period. Thus, it is not suitable for examining changing conditions at a given site. However, because many biosphere parameters (e.g., soil type, lake depth and well depth) are defined using probabilistic distributions, each probabilistic simulation does represent a slightly different biosphere.

Glaciation was identified as one of the most important transitional processes and a separate assessment (Davis et al. 1993, p. 349-360) was carried out even though glaciation will likely not happen with the next 10 000 years. The analysis indicated that predicted doses would not be much affected by the changes induced by glaciation.

BIOTRAC uses many simplifications. For example, radionuclide losses from the soil layer due to plant uptake are not accounted for in the model. In this way, recycling of radionuclides (e.g., use of compost material in gardens, animal waste on fields, runoff from fields to lakes, etc.) is implicitly modelled. Because of these simplifications, nuclide transfers in BIOTRAC are mainly unidirectional: from areas of high nuclide concentrations to areas of lower concentrations. Such simplifications should not result in an underestimation of exposure doses because they generally cause the nuclide mass in the biosphere to be overestimated.

BIOTRAC, the EIS biosphere model, was designed to model the postclosure assessment case study. However, it is almost completely generic; only parts of the geosphere/biosphere interface are site specific (e.g., the size of the catchment area is fixed and there are 3 groundwater discharge zones and a well). Therefore, BIOTRAC can be adapted for alternative site-specific applications with relatively minor changes (Davis et al. 1993, p. 389-396). At that time, any advances in model development would be taken advantage of and the most appropriate models for the conditions at a proposed disposal site would be used..

For future safety assessments, it is intended to review the status of biosphere models, particularly those used by other national nuclear waste management organizations, with respect to handling biosphere chnages. For example, it is possible that a small set of specific biospheres might be developed as a way to illustrate the effects of possible biosphere changes.

References

Davis, P.A., R. Zach, M.E. Stephens, B.D. Amiro, G.A. Bird, J.A.K. Reid, M.I. Sheppard and M. Stephenson. 1993. The disposal of Canada's nuclear fuel waste: The biosphere model, BIOTRAC, for postclosure assessment. Atomic Energy of Canada Limited Report, AECL-10720.

7.03.05.02.02 Safety Assessment - Postclosure - Biosphere - Models - BIOTRAC Soil Model

PARTICIPANT COMMENTS

Atomic Energy Control Board

in the biosphere submodel, a 136-coefficient regression model is deemed to provide a "satisfactory" match with the results of the detailed soil model SCEMR1, even though the fit is never better than a factor of two and never exceeds a factor of six (Biosphere PRD, p. 161). [Comment 2160, Source Document gov002, Page 70, Section C.8.5]

Environment Canada

Other issues identified as being of concern were: ... the validity of the BIOTRAC soil model (the use of the mixing cell approach for calculating concentrations in the soil may allow physically unrealistic behaviour to occur; the use of only four layers to model a total soil depth of up to 2.5 metres is insufficient to give a good description of the movement of water through the soil; and the bottom three soil layers are assumed to have the same physical and chemical properties). [Comment 877, Source Document gov003, Page 27, Section 2.13]

Natural Resources Canada

The two-step, SCEMR1-Multiple Regression approach described in section 6.3.1 and 6.3.2 seems inconsistent with the simpler compartment approach adopted in the other BIOTRAC sub-models.... A more credible alternative would be to derive analytical expressions for Css and Tss using dimensional analysis and simplified physics retained from the full SCEMR1 model.... Although perhaps no more accurate than the regression approach, a simple physics-based approach would be more easily defended and more consistent with other parts of BIOTRAC. [Comment 718, Source Document ph2gov001, Page bio3]

Scientific Review Group

radionuclide concentrations in the soil are predicted not by the well-known SCEMR-1 model, which has been validated experimentally at the Oak Ridge National Laboratory ... (R-Biosphere 1994: p.159f), but by a set of regression equations, the results of which, when compared with SCEMR-1 calculations, are stated "... to agree within a factor of 5 or 6 for the groundwater discharge, and within a factor of 2 or 3 for the irrigation-deposition case". Whether agreement within this range is acceptable is not explained. [Comment 427, Source Document tec004, Page 073, Section 6.5.4]

OPG RESPONSE

As noted, the soil model used in BIOTRAC (Davis et al. 1993) is not transparent. This BIOTRAC soil model uses a set of regression equations developed by fitting the results from many simulations of the (validated) SCEMR1 soil model, to calculate soil concentrations given the nuclide inputs into the soil layer from irrigation, atmospheric deposition and groundwater seepage. As such, there is no simple equation that can be written for mass conservation in the soil layer. In this sense, the soil model used in BIOTRAC is inconsistent with the simpler compartment approach adopted in the other BIOTRAC sub-models.

It is acknowledged that a simpler and more transparent soil model would have avoided some of the pitfalls identified in the comments: (1) the regression equations do not fit the SCEMR1 results as closely as desirable and, thus, there is a need to justify that the regression equations are acceptable, and (2) the use of large mixing cells in the SCEMR1 simulations, which raises questions concerning the validity of the SCEMR1simulations (tests were not carried out to confirm that the use of the large mixing cells were adequate, i.e., gave converged result) would have been avoided.

OPG has recently incorporated a simple physics-based soil model into its reference biosphere model, similar to that used in SR97 (Bergstrom et al. 1999). As stated in one of the comments, although a simple physics-based approach would perhaps not be more accurate than the regression approach, it would be more easily defended and more consistent with other parts of BIOTRAC.

References

Bergström, U., S. Nordlinder and I. Aggeryd. 1999. Models for dose assessments. Modules for various biosphere types. SKB Technical Report TR-99-14.

Davis, P.A., R. Zach, M.E. Stephens, B.D. Amiro, G.A. Bird, J.A.K. Reid, M.I. Sheppard and M. Stephenson. 1993. The disposal of Canada's nuclear fuel waste: The biosphere model, BIOTRAC, for postclosure assessment. Atomic Energy of Canada Limited Report, AECL-10720.

7.03.05.02.03 Safety Assessment - Postclosure - Biosphere - Models - CALDOS PARTICIPANT COMMENTS

Scientific Review Group

there are a number of assumptions used in developing or applying the food-chain model CALDOS that appear to be unsupported or to be conveniences used to reduce demands on computer time. These include the treatment of the biological inter-trophic system as a simple chain rather than a food web, and calculating the transfer of radionuclides as a one-dimensional, one-way instantaneous process that can be represented by a single transfer coefficient (R-Biosphere 1993: p.252). [Comment 275, Source Document tec004, Page 233, Section H-2.3]

The development of the CALDOS food chain model depends upon an assumption that the transfer of radionuclides from one compartment in the food chain to another occurs in linear fashion, regardless of the concentration in the source compartment, the presence of other elements, or the ability of an organism to regulate uptake (R-Biosphere 1993: p.265, 231ff).... The assumption however implies that vault-derived radionuclides are present in the biosphere in very small quantities only (R-Biosphere 1993: p.265), and it neglects the possibility that over long time periods small but persistent changes or non-steady-state biological action could cause significant changes in food chain transfers. These issues warrant further examination. [Comment 276, Source Document tec004, Page 233, Section H-2.3]

The CALDOS model assumes that food-chain transfer and accumulation of radionuclides are independent of the concentration of the contaminant in plants and animals, provided the concentration is not high (R-Biosphere 1993: p.208,362). It is not clear at what level the concentration would be such that the process would no longer be independent of the concentration; or whether this level would be different over very long time periods. [Comment 285, Source Document tec004, Page 236, Section H-2.3]

statements ... that may ... warrant further explanation ... "Because garden soils may consists of sediment ... we account indirectly for external doses from (exposure from) contaminated shorelines and beaches" (R-Biosphere 1993: p.141,224). [Comment 286, Source Document tec004, Page 236, Section H-2.3]

statements ... that may ... warrant further explanation ... "Equation 8.45 conservatively predicts an inhalation rate sufficient to allow complete oxidation of all the ingested carbohydrates, fat, and protein" (R-Biosphere 1993: p.229). [Comment 287, Source Document tec004, Page 236, Section H-2.3]

OPG RESPONSE

The food-chain model CALDOS used in BIOTRAC is similar to food-chain models used internationally for assessment of nuclear waste disposal, e.g., for the recent SKB assessment (Bergstrom et al 1999), and for nuclear facilities (CSA 1987; NCRP 1996). Consequently, the methodology used in CALDOS has widespread international acceptance.

Furthermore, given the predicted low concentrations of nuclides reaching the biosphere from the waste fuel repository (Goodwin et al. 1994), the assumption that the food-chain transfer and accumulation of radionuclides are independent of nuclide concentration is reasonable. However, it is recognized that it would have been useful if the limits of validity of this assumption had been stated in the BIOTRAC report (Davis et al. 1993).

It is also accepted that further explanations should have been added to the report to clarify any statements that are unclear or difficult to understand. For the particular statements referred to, the following explanations can be made: (1) Humans are exposed to external radiation when walking on contaminated beaches (CSA, 1987). BIOTRAC does not explicitly include this exposure pathway in the calculation of doses. However, this exposure pathway is indirectly accounted for because

sediments can be used as garden soils and hence external exposure to sediments (which are more contaminated than beach sand) is included in the dose calculations, for those scenarios in which sediments are used as garden soils. (2) The inhalation rate is conservative because not all ingested food is necessarily oxidized. The median inhalation rate calculated in this fashion is 8617 m3/a which is larger than the value of 8400 m3/a used in CSA (1987).

References

Davis, P.A., R. Zach, M.E. Stephens, B.D. Amiro, G.A. Bird, J.A.K. Reid, M.I. Sheppard and M. Stephenson. 1993. The disposal of Canada's nuclear fuel waste: The biosphere model, BIOTRAC, for postclosure assessment. Atomic Energy of Canada Limited Report, AECL-10720.

Bergström, U., S. Nordlinder and I. Aggeryd. 1999. Models for dose assessments. Modules for various biosphere types. SKB Technical Report TR-99-14.

Canadian Standards Association (CSA). 1987. Guidelines for calculating derived release limits for radioactive material in airborne and liquid effluents for normal operation of nuclear facilities. CSA Report CAN/CSA-N288.1-M87

National Council on Radiation Protection and Measurements (NCRP). 1996. Screening models for release of radionuclides to atmosphere, surface water and ground. NRCP Report No. 123 I.

7.03.05.03 Safety Assessment - Postclosure - Biosphere - Data Usage PARTICIPANT COMMENTS

Scientific Review Group

A major concern is the apparent lack of demonstrated connections between site investigation methods and the biosphere (BIOTRAC, R-Biosphere 1994) ... models [Comment 1, Source Document tec004, Page 102, Section A-S]

OPG RESPONSE

The Site Screening report (Davison et al. 1994) was mainly focused on the geotechnical issues of site screening and evaluation. Therefore, issues related to the biosphere were not addressed in detail. However, as stated in Section 3.7 (Surface Environment and Environmental Sensitivity) of the Site Screening report "Many of the features of the surface environment important to siting are most relevant to and are discussed in the context of the preclosure phases of the disposal project (Grondin et al. 1994). For example, the recognition and avoidance of essential habitat for endangered species would be part of the siting process. This would be an immediate preclosure concern relevant to the site evaluation, construction and operational phases of the project."

Further, a brief discussion of the attributes of a suitable site for the purposes of postclosure assessment is discussed in Section 3.7 of the Site Screening report (Davison et al. 1994). For example, a site with no valuable agricultural resources would be preferred (Table 3-1, Davison et al. 1994). However, a direct connection between optimal siting requirements and BIOTRAC is never made. It is recognized that such a connection should be made, i.e., how site characteristics will be used to derive the required biosphere model parameters. Nevertheless, it is likely that a site that meets the requirements in the Site Screening report (Table 3-1, Davison et al. 1994) and Preclosure report would also be suitable for postclosure requirements, i.e., regulatory dose limits would also be met.

References

Davison, C.C, A. Brown, R.A. Everitt, M. Gascoyne, E.T. Kozak, G.S. Lodha, C.D. Martin, N.M. Sonnawala, D.R. Stevenson, G.A. Thorne, S.H. Whitaker. 1994. The Disposal of Canada's Nuclear Fuel Waste: Site Screening and Site Evaluation Technology. Atomic Energy of Canada Report, AECL-10713.

Grondin, L., K. Johansen, W.C. Cheng, M. Fearn-Duffy, C.R. Frost, T.F. Kempe, J. Lockhart-Grace, M. Paez-Victor, H.E. Reid, S.B. Russell, C.H. Ulster, J.E. Villagran, M. Zeya. 1994. The Disposal of Canada's Nuclear Fuel Waste: Preclosure Assessment of a Conceptual System. Atomic Energy of Canada Report, AECL-10716.

7.03.05.04 Safety Assessment - Postclosure - Biosphere - Parameters

7.03.05.04.01 Safety Assessment - Postclosure - Biosphere - Parameters - Dose Conversion Factors

PARTICIPANT COMMENTS

Atomic Energy Control Board

The dose estimates do not use the ICRP's most recently recommended Dose Conversion factors (DCFs) or Risk Factors... AECB staff recognize that changing the DCFs and risk conversion factors alone would not increase the mean estimated does above the AECB risk criterion (i.e., 10-6 per year). However, since the dose arising from the dominant contributor to total dose (i.e., 129I) is underestimated, AECL should assess the changes to the principal assessment endpoints that would result from the use of DCFs based on the ICRP 60 recommendations (ICRP, 1991). [Comment 648, Source Document gov002, Page 62, Section C.5.1]

Energy Probe (Rubin)

The risks (only individual) of cancer (only fatal) are intentionally underestimated throughout, "as specified by the AECB in R-104 (Appendix B), using 0.02 as the probability of a health effect (fatal cancer or serious genetic effect) per sievert. [EIS, p. 297]" ... the use of an obsolete, non-conservative risk factor ... is absurdly deficient. [Comment 2054, Source Document pub014r, Page 5]

Health Canada

The EIS does not quantitatively incorporate the new ICRP risk coefficient of 0.073/Sv for fatal and non-fatal cancers and genetic effects. [Comment 920, Source Document gov006, Page 03]

A comparison between DCFs used in the model, and those recommended by ICRP 67 show that in most cases, these are similar. However, the ingestion DCF for iodine-129 as given in ICRP 67 is significantly larger than the combined inhalation-ingestion DCF used in the predictive model. [Comment 921, Source Document gov006, Page 03]

The EIS should discuss the use of ICRP Reference Man as an adequate model of a northern, and in particular, an aboriginal population. Is it valid to use a single reference individual for the critical group, or should a distribution of human characteristics be used in order to account for factors that may result in higher exposures. [Comment 922, Source Document gov006, Page 03]

The new ICRP risk coefficient of 0.073/Sv for cancers and genetic disorders should be used throughout all the documents. [Comment 962, Source Document gov006, Page 17]

There should be a justification for the choice of Dose Conversion Factors and for the use of ICRP Reference Man parameters. [Comment 963, Source Document gov006, Page 17]

The proponent insists on continuing to use the outdated risk factor of 0.02 per Sievert for fatal cancers and genetic effects. AECL ignores the more recent recommendations of the ICRP (0.05 per Sievert for fatal cancers or 0.07 per Sievert to include genetic effects and non-fatal cancers as well) and the imminent changes to AECB regulations which reflect the modified risk factors. [Comment 985, Source Document ph2gov011, Page 04]

The ICRP risk factor of 0.05 per Sievert for fatal cancer can be considered the best current estimate by the international scientific community. However, like other estimates, it is subject to uncertainty.... the proponent should demonstrate the effect of these uncertainties in risk before moving to its conclusions. [Comment 986, Source Document ph2gov011, Page 05]

the proponent has relied on dose conversion factors based on the work of Johnson and Dunford rather than the updated dose conversion factors of the ICRP.... One of the requirements of the waste disposal concept is the flexibility to incorporate new information. The proponent should have demonstrated its ability to do so by using the most recent dose and risk factors [Comment 991, Source Document ph2gov011, Page 07]

International Institute of Concern for Public Health (Bertell)

Many of us in the research community, think that the risk estimate should be 20 cancer deaths per hundred Person Sievert, instead of the 5 cancer deaths assumed by the ICRP, meaning that the limit needs to be below 0.05 mSv per year, just to prevent deaths from cancer. [Comment 2120, Source Document ph2tec002, Page 07]

National Action Committee on the Status of Women

The ICRP conducts dose estimations using a model known as "reference man".... The use of such models does not fully account for differential impacts on women, whose body fat content, physiology, average weight and height, and reproductive systems differ dramatically from men's. The use of "reference man" also discounts effects on the young, the aged, and those in less than ideal physical condition. In determining exposure pathways, pathways to men are the basis for allowable estimates [Comment 1286, Source Document pub026, Page 30, Section 7.2.7]

The EIS also states that "to estimate infant dose, the characteristics of a one year old are used."... The EIS does not elucidate for us whether or not the use of a standard for a one year old is appropriate for an organism growing at a much faster rate. The lack of discussion of these limitations is a major deficiency in the EIS. [Comment 1287, Source Document pub026, Page 30, Section 7.2.7]

Northwatch (Lloyd)

Additional Key Information Deficiencies Identified in Phase II Technical Hearings (June 1996) ... - dose conversion factors (comparative discussion of AECL / NRCan) [Comment 1552, Source Document ph2tec045, Page 24]

Scientific Review Group

AECL's human health assessment did not use the recently-updated dose-conversion factors of the ICRP. Although AECL reported that the use of the older DCF's does not lead to systematic underestimation of doses in BIOTRAC, the use of the updated DCF's in SYVAC3-CC3 would have been preferred. [Comment 185, Source Document tec004, Page 188, Section E-3.2]

OPG RESPONSE

OPG accepts that the new ICRP risk coefficient of 0.073/Sv and the new ICRP60 (or subsequent) DCFs will be used in future assessments. Garisto (2002) details the values presently in use, and an example application is the OPG Third Case Study exercise.

Palattao et al. (1997) studied how the results of the EIS postclosure assessment case study would have been affected if the ICRP 60 dose conversion factors had been used. It was concluded that the total dose at 10,000 years, which is dominated by I-129, would have increased by about 67 % if the ICRP 60 DCFs were used. Use of the ICRP 60 dose and risk conversion factors would have increased the estimated risk from I-129 by about a factor of 6. For comparison, the maximum EIS estimated dose at 10,000 years was orders of magnitude lower than the regulatory dose limit (Goodwin et al. 1994). Even at 100,000 years, the maximum dose (mainly from I-129) was about a factor of 36 lower than the regulatory dose limit used in the EIS (Goodwin et al. 1994, p.201,202).

A discussion of the use of ICRP reference man in the dose calculations is given in Zach et al. (1996), where it is concluded that, for radiation protection, ICRP reference man is an adequate description of

all Canadians living on the Shield.

References

Garisto, F. 2002. Radionuclide and element specific data for the Radionuclide Screening Model Version 1.1. OPG report 06819-REP-01200-10038 R01.

Goodwin, B.W., D.B. McConnell, T.H. Andres, W.C. Hajas, D.M. LeNeveu, T.W. Melnyk, G.R. Sherman, M.E. Stephens, J.G. Szekely, P.C. Bera, C.M. Cosgrove, K.D. Dougan, S.B. Keeling, C.I. Kitson, B.C. Kummen, S.E. Oliver, K. Witzke, L. Wojciechowski and A.G. Wikjord. 1994. The disposal of Canada's nuclear fuel waste: Postclosure assessment of a reference system. Atomic Energy of Canada Limited Report AECL-10717.

Palattao, M.V.B., W.C. Hajas and B.W. Goodwin. 1997. Evaluation of the used of ICRP 60 dose conversion factors in a postclosure assessment of a deep geological disposal system. Atomic Energy of Canada Limited Report AECL-11734.

Zach, R., J.G. Szekely, G.A. Bird, W.C. Hajas, C.R. Macdonald and S.C. Sheppard. 1996. Alternative human characteristics and lifestyles in the BIOTRAC biosphere model for assessing Canada's nuclear fuel waste disposal concept. Atomic Energy of Canada Limited Report TR-719.

7.03.05.04.02 Safety Assessment - Postclosure - Biosphere - Parameters -Transfer Coefficients

PARTICIPANT COMMENTS

Scientific Review Group

The transfer coefficients for non-human target organisms are based mostly on domesticated and cultivated species, because that is where data are available (R-Biosphere 1993; pp.231ff, 264, 381) and it is assumed that these data cover the likely range of organisms in a southern Canadian Shield ecosystem. This assumption appears to overlook evidence that the most contaminated soils could also occur in wetlands with groundwater discharge; that some coniferous trees, berry fruits and lichens are known to accumulate high radionuclide concentrations (Sheard et al. 1988); that grouping longlived mammals such as moose and bear with short-lived species such as voles makes a figure for a generic mammal of guestionable validity; and that data from domestic poultry are unlikely to be representative of the range of seed-eating, insectivorous or raptorial birds. The use of the selected generic target organism would be more acceptable if there had been discussion or justification of the selection of probability density functions to reflect what is known about wild organisms, and the criteria for screening the parameters had been described. The claim that " ... agricultural plants have greater transfer coefficients than perennial native species ... [and] ... most native species such as trees will have transfer coefficients in the lower range of the distributions used in our model" (R-Biosphere 1993: p.382) is not referenced or substantiated. Natural ecosystems include annuals as well as perennials, and even if most native species may have low transfer coefficients, it is the few which may have high coefficients that could be important to the delivered dose. [Comment 280, Source Document tec004, Page 234, Section H-2.3]

OPG RESPONSE

In the EIS, the non-human target organisms, i.e., plant, mammals, bird and fish, are not specific species but generic ones. Food chain parameters for these species were taken to be the same as for the corresponding domesticated animals and cultivated species. The applicability of these data to the non-human target organisms was briefly discussed in the EIS and it was generally concluded that the wide distributions used for the transfer factors meant that the selected values would include many wild species. It was, however, acknowledged in Zach and Sheppard (1992, p. 58) that there are limitations in using the human food types in BIOTRAC to represent plant and animal species of the Shield. For example, TE PLANT is not representative of all the species ranging from small annuals to long-lived perennials and the animal food types may not be representative of potentially sensitive indicator species. However, it was decided that in "spite of these limitations, the use of our food types to help demonstrate environmental protection would seem to be appropriate, given the limited database for organisms unrelated to these food types". Perhaps, as suggested in the comment, these approximations would have been more acceptable if the EIS had contained a detailed "discussion or justification of the selection of probability density functions to reflect what is known about wild organisms, and the criteria for screening the parameters had been described."

Nevertheless, the results presented in the EIS indicated that: (1) the doses received by non-human target organisms would be much lower than background doses (Goodwin et al. 1994). This result would likely not have been different if data for specific target organisms were used in the calculations; and (2) the concentrations of chemically toxic elements in the biosphere, resulting from used fuel disposal, would be much smaller than the background concentrations of these elements (Goodwin et al. 1994). It is not expected that non-human organisms would be affected by such low contaminant concentrations.

The subject of ecological risk assessment has progressed greatly since the EIS was prepared and additional data on non-human target organisms have become available. It is acknowledged that the use of generic target organisms would probably not be acceptable, particularly after a repository site has been selected. Therefore, future assessments would likely include estimates of radiological and

chemical doses to (site-specific) valued ecosystem components. If data for such species are unavailable, they would have to be conservatively estimated from existing data for similar species.

Recently, specific representative Canadian Shield biota have been identified (Sheppard 2002) for potential use in an ecological risk assessment of used fuel disposal in a geologic repository.

References

Goodwin, B.W., D.B. McConnell, T.H. Andres, W.C. Hajas, D.M. LeNeveu, T.W. Melnyk, G.R. Sherman, M.E. Stephens, J.G. Szekely, P.C. Bera, C.M. Cosgrove, K.D. Dougan, S.B. Keeling, C.I. Kitson, B.C. Kummen, S.E. Oliver, K. Witzke, L. Wojciechowski and A.G. Wikjord. 1994. The disposal of Canada's nuclear fuel waste: Postclosure assessment of a reference system. Atomic Energy of Canada Limited Report AECL-10717.

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7.03.05.04.03 Safety Assessment - Postclosure - Biosphere - Parameters - Fish Ingestion Rate

PARTICIPANT COMMENTS

Scientific Review Group

The given ingestion rate for fish of 10 kg/person per year (R-Biosphere 1993: p.229) appears very low for many aboriginal groups and much lower than U.S. EPA data in which the upper 95th percentile ranges to 67 kg/year. [Comment 288, Source Document tec004, Page 236, Section H-2.3]

OPG RESPONSE

U.S. EPA (1997) recommends an average fish ingestion rate of 7.3 kg/year for the whole population and 25.6 kg/year for the Native American subsistence population. In the EIS model, the mean fish ingestion rate 10 kg/year. However, a range of fish ingestion rates were actually considered in the EIS probabilistic analysis. The 95th percentile fish ingestion rate in the EIS would have been about 200 kg/year (Davis et al. p. 256).

Therefore, the EIS judged that a range of human lifestyles and characteristics had been adequately addressed, including aboriginal. However, it is recognized now that it will be necessary in future to analyze specific lifestyles of interest, rather than deferring to the details of the probabilistic analysis.

It should be noted that Zach et al. (1996) subsequently studied the effect of specific alternative human characteristics and lifestyles on the predicted EIS doses. Based on the results of this study, it was concluded that the probabilistic postclosure assessment case study was "representative of the full spectrum of diets and lifestyles that might be encountered on the Shield including those of aboriginal peoples and northerner." In particular, the study included a critical group which obtained 75% of their caloric requirements from fish ingestion and the rest from plant products, red meat and poultry/eggs. (The fish ingestion rate for such a group is about 750 kg/year.) The dose for this particular group was much smaller than that predicted for the critical group in the EIS study.

References

Davis, P.A., R. Zach, M.E. Stephens, B.D. Amiro, G.A. Bird, J.A.K. Reid, M.I. Sheppard and M. Stephenson. 1993. The disposal of Canada's nuclear fuel waste: The biosphere model, BIOTRAC, for postclosure assessment. Atomic Energy of Canada Limited Report, AECL-10720.

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7.03.05.04.04 Safety Assessment - Postclosure - Biosphere - Parameters -Concentration Ratios

PARTICIPANT COMMENTS

Scientific Review Group

AECL did not attempt to define the range of radionuclide concentration ratios for each element, but adopts the same deviation from the mean for all elements (R-Biosphere 1993: p.233). This practice appears to ignore the fact that different radionuclides may behave quite differently in transfer from soil to plant. [Comment 289, Source Document tec004, Page 236, Section H-2.3]

OPG RESPONSE

The mean Bv values (plant/soil concentration ratio) adopted for the EIS (Davies et al. 1993, p.233) are element dependent. Thus, the EIS does not ignore the fact that different radionuclides may behave quite differently in transfer from soil to plant.

The Biosphere PRD states that variations in the plant/soil concentration values have not been reported extensively (Davies et al. 1993) and that the published results produced varied results. "Variation appears to be mainly a function of the number of samples and the range of conditions under which Bvi was measured rather than of the physical or chemical properties of the system studied." Zach and Sheppard (1992) reviewed the available information and concluded that there was insufficient data concerning the variation in Bv values to assign reliable but different GSDs for the different elements. They recommended a GSD of 10 for all elements, which was used in the EIS. This GSD is close to 9.0, the arithmetic mean of the GSDs reported by Baes et al. (1984), the reference from which most Bv values were taken, It should be noted that a GSD of 10 means that the 95% confidence intervals span about 4 orders of magnitude.

The statement in Zach and Sheppard (1992) that the "variation appears to be mainly a function of the number of samples and the range of conditions under which Bvi was measured rather than of the physical or chemical properties of the system studied" does not imply that the "available information on ratios appears to be an artifact of the sampling" but rather that the observed variations in the Bv values in the available studies depended more on the number of Bv values measured and the range of conditions studied than on the properties of the element or soil used in the study. Perhaps, the text in the biosphere PRD should have been rephrased so as to avoid any possible confusion.

References

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7.03.05.04.05 Safety Assessment - Postclosure - Biosphere - Parameters -Occupancy Factors

PARTICIPANT COMMENTS

Scientific Review Group

The water occupancy factor, building occupancy factor, and ground occupancy factors, (R-Biosphere 1993: pp.244ff,251,497-515) use numbers that differ from the standard (AIHC 1994). Whether or not these differences are significant needs to be explained, particularly because it is numbers such as these, regardless of their significance, that may be questioned by the public. [Comment 290, Source Document tec004, Page 237, Section H-2.3]

OPG RESPONSE

The building occupancy factor (0.8) and ground occupancy factor (0.2) used in BIOTRAC (Davis et al. 1993) were obtained from the CSA N288.1 Standard (CSA 1987), which provides guidelines for calculating derived release limits normal operation of nuclear facilities. The water occupancy factor was conservatively selected to be equal to twice the value recommended in CSA (1987). The referenced report (AIHC 1994) was not available for comparison. However, occupancy factors can be found in U.S. EPA's Exposure Factors Handbook (U.S. EPA 1997). In this latter report the average water, building and ground occupancy factors are about 0.014, 0.87 and 0.13. These are not much different from those used in BIOTRAC. Since the EIS total doses are not very sensitive to the values of the occupancy factors (Goodwin et al. 1994), these difference will not affect the total doses predicted by BIOTRAC.

References

Canadian Standards Association (CSA). 1987. Guidelines for calculating derived release limits for radioactive material in airborne and liquid effluents for normal operation of nuclear facilities. Canadian Standards Association Standard CAN/CSA-N288.1-M87.

Davis, P.A., R. Zach, M.E. Stephens, B.D. Amiro, G.A. Bird, J.A.K. Reid, M.I. Sheppard and M. Stephenson. 1993. The disposal of Canada's nuclear fuel waste: The biosphere model, BIOTRAC, for postclosure assessment. Atomic Energy of Canada Limited Report, AECL-10720.

Goodwin, B.W., D.B. McConnell, T.H. Andres, W.C. Hajas, D.M. LeNeveu, T.W. Melnyk, G.R. Sherman, M.E. Stephens, J.G. Szekely, P.C. Bera, C.M. Cosgrove, K.D. Dougan, S.B. Keeling, C.I. Kitson, B.C. Kummen, S.E. Oliver, K. Witzke, L. Wojciechowski, and A.G. Wikjord. 1994. The disposal of Canada's nuclear fuel waste: Postclosure assessment of a reference system. Atomic Energy of Canada Limited Report AECL-10717.

United States Environmental Protection Agency (U.S. EPA). 1997. Exposure Factors Handbook. United States Environmental Protection Agency Report EPA/600/P-95/002Fa.
7.03.05.04.06 Safety Assessment - Postclosure - Biosphere - Parameters - Food Intake Rates

PARTICIPANT COMMENTS

Scientific Review Group

CALDOS treats in a probabilistic manner the ingestion rates of feed, forage and drinking water for animals consumed by humans as food (R-Biosphere 1993: p.252). These same generic animals are used in the modelling of exposure to non-human biota (R-Biosphere 1993: p.366). It would be useful to compare these figures (R-Biosphere 1993: Appendix D) with the equations for food intake rates for specified body weights of birds and mammals (U.S. EPA 1993). [Comment 291, Source Document tec004, Page 237, Section H-2.3]

OPG RESPONSE

CALDOS uses the following average feed ingestion rates for dairy cows, beef cattle and chickens: 12, 10 and 0.08 kg dry weight/day (assuming food water content of 80%) and the following average drinking water ingestion rates for dairy cows, beef cattle and chickens: 60, 40 and 0.4 L/day (Davies et al. 1993, p.253). These are similar to the values used in the CSA N288.1 (1987), which provides guidelines for calculating derived release limits for normal operation of nuclear facilities: feed ingestion rates for dairy cows, beef cattle and chickens of 10, 10, 0.1 kg dry weight/day and water ingestion rates for dairy cows, beef cattle and chickens of 80, 50, 0.3 L/d.

Food and water ingestion rates can also be calculated from the allometric equations in U.S. EPA (1993) assuming body weights for dairy cows, beef cattle and chickens of 500, 350 and 2.2 kg, respectively (CSA 1987). Using these allometric equations, it is found that feed ingestion rates for dairy cows, beef cattle and chickens are 8, 6.2 and 0.1 kg dry weight/day and drinking water ingestion rates are about 30, 20 and 0.1 L/day, respectively. (The latter water ingestion rates do not include water obtained from food.) Thus, the ingestion rates used in CALDOS are generally conservative compared to the values calculated from U.S. EPA (1993).

References

Canadian Standards Association (CSA). 1987. Guidelines for calculating derived release limits for radioactive material in airborne and liquid effluents for normal operation of nuclear facilities. Canadian Standards Association Standard CAN/CSA-N288.1-M87.

United States Environmental Protection Agency (U.S. EPA). 1993. Wildlife Exposure Factors Handbook. United States Environmental Protection Agency Report EPA/600/R-93/187.

7.03.05.04.07 Safety Assessment - Postclosure - Biosphere - Parameters - Stable lodine

PARTICIPANT COMMENTS

Atomic Energy Control Board

The assumed background concentrations for stable iodide in the biosphere model are based on WRA data, which are not conservative with respect to Canadian Shield data. [Comment 652, Source Document gov002, Page 63, Section C.5.3]

OPG RESPONSE

The stable iodine groundwater concentration is used to determine the upper groundwater limit to the internal I-129 dose (Davis et al. 1993, p. 221).

In the EIS, the stable iodine concentration in groundwater was described using a uniform distribution ranging from 5E-3 to 2E-2 mg/L (Davies et al. 1993, p. 262). This distribution was based on data from the Whiteshell Research Area (WRA). Since the safety assessment calculations in the EIS were carried out on a hypothetical reference disposal system having geosphere characteristics similar to those at the WRA, it was appropriate to use groundwater data from the WRA to define the stable iodine background concentrations.

Sheppard and Gascoyne (1997) have recently compiled a database of groundwater iodine, chlorine and carbon concentrations. Their study shows that for Canadian Shield groundwaters that are likely to be used for irrigation water (TDS < 3500 mg/L and depths < 200 m) the stable iodine concentrations are lognormally distributed with a geometric mean of 0.007 mg/L and a geometric standard deviation of 8, with lower and upper bounds of 0.0001 mg/L and 0.4 mg/L, respectively.

For the WRA, the currently recommended lognormal distribution function for the iodine concentration in groundwater has a geometric mean of 0.003 mg/L and a geometric standard deviation of 4, with lower and upper bounds of 0.0002 mg/L and 0.05 mg/L, respectively (Sheppard and Gascoyne1997). Both the median and lower bound of this distribution function are lower than the corresponding values used in the EIS. Consequently, because lower values of the stable iodine groundwater concentrations lead to larger I-129 doses, the new data indicate that the stable iodine groundwater concentrations used in the EIS were non-conservative. However, it should be noted that the sensitivity analyses carried out for the biosphere model (Goodwin et al. 1994, p.506) did not find the stable iodine groundwater concentration.

The above discussion indicates the importance of using site-specific data in the safety assessment. After a repository site is selected, OPG will ensure that measurements of groundwater composition will include the determination of iodine, chlorine and carbon concentrations.

References

Davis, P.A., R. Zach, M.E. Stephens, B.D. Amiro, G.A. Bird, J.A.K. Reid, M.I. Sheppard and M. Stephenson. 1993. The disposal of Canada's nuclear fuel waste: The biosphere model, BIOTRAC, for postclosure assessment. Atomic Energy of Canada Limited Report, AECL-10720.

Goodwin, B.W., D.B. McConnell, T.H. Andres, W.C. Hajas, D.M. LeNeveu, T.W. Melnyk, G.R. Sherman, M.E. Stephens, J.G. Szekely, P.C. Bera, C.M. Cosgrove, K.D. Dougan, S.B. Keeling, C.I. Kitson, B.C. Kummen, S.E. Oliver, K. Witzke, L. Wojciechowski and A.G. Wikjord. 1994. The disposal of Canada's nuclear fuel waste: Postclosure assessment of a reference system. Atomic Energy of Canada Limited Report AECL-10717.

Sheppard, S.C. and M. Gascoyne. 1997. Supplement to the database of groundwater iodine, chlorine

and carbon concentrations. Ontario Hydro Report 06819-REP-01200-0005-R00.

7.03.05.04.08 Safety Assessment - Postclosure - Biosphere - Parameters - Plant-Soil Concentration Ratio

PARTICIPANT COMMENTS

Natural Resources Canada

daily and, more importantly, seasonal variations in plant uptake of nuclides are considerable, with highest concentrations occurring in the spring after the soil thaw. These peak concentrations may be significantly higher than annual mean values accounted for in the model. [Comment 719, Source Document ph2gov001, Page bio3]

The ... plant-soil concentration ratio ... varies so significantly among plant species and in differing environmental conditions ... that the geometric mean becomes a misleading figure. The barriers to element uptake that different species establish render these data significantly in error for many of those species.... the authors should further justify their choice of a geometric standard deviation of 10 and why such a guess is conservative. If experimental data do not exist for this parameter, then clearly acquisition of such data should be a priority. [Comment 720, Source Document ph2gov001, Page bio3]

OPG RESPONSE

Seasonal variations in the rate of nuclide uptake by plants do occur. However, what is important is the total nuclide uptake by the plant at the time the plant is harvested. This quantity, the plant/soil concentration factor, is determined from experimental data obtained from plants grown in contaminated soil and harvested at the end of the plant growth period. For plants digested by animals, e.g., forage grass, that can be eaten at any time during their growth period, the annual mean value of the plant/soil concentration factor should be used, since animals ingest plants throughout the growing season and, hence, any seasonal variations would tend to average out.

It is true that the plant/soil concentration ratio or Bv factor can vary significantly among plant species and in differing environmental conditions. This could explain why measured Bv values show large variations (Zach and Sheppard 1992). The plant/soil concentration ratio was found to be an important biosphere parameter (Goodwin et al. 1994, p.507). Thus, plant/soil concentration factors appropriate for the repository site should be used, if such data are available. Furthermore, consideration should be given to using plant-specific plant/soil concentration ratios, as was done in SR97 assessment (SKB 1999), rather than generic values. This latter change would tend to reduce the geometric standard deviation of the Bv value.

Recently a review of recommended biosphere model values for iodine was done (Sheppard et al. 2002) and an updated plant-soil concentration ratio of 0.008 kg dry soil/kg fresh plant was recommended for iodine (the value used in the EIS was 0.038 kg dry soil/kg fresh plant). Furthermore, the current OPG safety assessment code SCC404 differentiates between plants used for forage and garden plants.

Bv factors tend to be lognormally distributed (Zach and Sheppard 1992, p.75). Variation in Bv values seem to be mainly a function of the range of conditions under which they were measured, e.g., plant species, soil types, climate, etc. Because of a lack of data, element-specific geometric standard deviations (GSD) for the Bv factors were not defined in the EIS, rather a GSD of 10 was used for all Bv values. This is close to the arithmetic mean of the GSDs reported by Baes et al. (1984), from which most Bv values were taken, was 9.0. It should be noted that a GSD of 10 means that the 95% confidence intervals span about 4 orders of magnitude.

References

Goodwin, B.W., D.B. McConnell, T.H. Andres, W.C. Hajas, D.M. LeNeveu, T.W. Melnyk, G.R. Sherman, M.E. Stephens, J.G. Szekely, P.C. Bera, C.M. Cosgrove, K.D. Dougan, S.B. Keeling, C.I. Kitson, B.C. Kummen, S.E. Oliver, K. Witzke, L. Wojciechowski, and A.G. Wikjord. 1994. The disposal of Canada's nuclear fuel waste: Postclosure assessment of a reference system. Atomic Energy of Canada Limited Report AECL-10717.

Sheppard, M.I., S.C. Sheppard and B. Sanipelli. 2002. Recommended biosphere values for iodine. OPG Report 06819-REP-01200-10090.

Swedish Nuclear Fuel and Waste Management Co. (SKB). 1999. Deep repository for spent nuclear fuel. SR 97 – Post-closure safety. SKB Technical Report TR-99-06.

Zach, R. and S.C. Sheppard. 1992. The food-chain and dose submodel, CALDOS, for the assessment of Canada's nuclear fuel waste management concept. Atomic Energy of Canada Limited Report AECL-10165.

Baes, C.F., III, R.D. Sharp, A.L. Sjoreen and R.W. Shor. 1984. A review and analysis of parameters for assessing transport of environmentally released radionuclides through agriculture. Oak Ridge National Laboratory Report ORNL-5786.

7.03.05.05 Safety Assessment - Postclosure - Biosphere - Research PARTICIPANT COMMENTS

Canadian Coalition for Ecology, Ethics and Religion

Initiate research to discover effects on non-human species of exposure to radiation and chemical toxicity of used fuel. [Comment 1852, Source Document ph2pub011, Page 1]

it seems more than likely that the radiation dose-response relationship cannot be automatically assumed to be the same for humans and other species, or even other mammals. The assumption also overlooks the special concerns of rare and endangered species, for which the loss of any individuals threatens the survival of that species, and by extension reduces biodiversity. A further concern is that if and when long-lived radionuclides are released into a groundwater discharge area, they will eventually reach the biosphere, where they will be taken up and transported by biota as well as wind and water, and will circulate through the biosphere indefinitely. It is not clear how, or even if it is possible, to identify a critical group of non-human species or their location. Nor how else to protect other forms of life. This is an area requiring more research rather than an ill-conceived assumption. [Comment 1855, Source Document ph2pub021, Page 55, Section 08.4]

It would appear that the use of increased frequency of chromosomal aberations as an early indicator of biochemical stress, in this case associated with ionizing radiation, may be useful.... This area is worthy of further study. [Comment 1837, Source Document phpub043, Page 28, Section 11]

Joint Committee of the Canadian Academy of Engineering and the Royal Society of Canada

It appears that the effects of radionuclides and other waste contaminants on the environment is open to question. Given the uncertainties of the long term effects of the waste products and their derivatives on animal and plant life, there is need for vigilant monitoring of these products in the environment and further research on their effects on life. This research could continue concurrently with the siting process which is the first step in implementation. [Comment 1155, Source Document ph2tec007, Page 04]

OECD/NEA Review Group

The biosphere work has availed itself of the international cooperation within the framework of the BIOMOVS programme. The development and use of a reference biosphere within this international context is a useful and important approach. The group encourages the continued involvement of the Canadian programme in those activities and, in particular, further analyses and documentation of the recent comparisons of Canadian and other models. These intercomparisons enhance confidence in the results of the biosphere analyses. [Comment 1218, Source Document tec001, Page 11, Section 3.3]

Scientific Review Group

Given the many statements in R-Biosphere to the effect that present data are inadequate or that the understanding of biospheric processes or of the rate of transfer of radionuclides is lacking or is uncertain, it is surprising that there is no coherent outline or summary of priority areas of investigation where further research is needed. There are several indications that the sub-models of BIOTRAC are evolving and will be improved, but no statement of what research is needed to bring about the improvements. [Comment 265, Source Document tec004, Page 232, Section H-2.2]

The Environmental Assessment Panel, and AECL, therefore are presented with a dilemma. To overcome the major difficulties with BIOTRAC noted in this evaluation, and to obtain the new data needed through observation and experimentation (R-Biosphere 1993: p.388) will be difficult and expensive. The question arises how much effort should be devoted to this very difficult, expensive, presently not fully satisfactory part of the concept that is of highest priority from the public and decision point of view but possibly not very important in terms of assessments of ultimate safety or the technical success of the concept. How this question is addressed, and how a balance will be kept between addressing adequately issues of major public interest and not wasting money on issues of minor importance from a scientific assessment of technical priority may be critical in determining the credibility and acceptability of the concept. [Comment 299, Source Document tec004, Page 239, Section H-4]

United Church of Canada

More studies need to be undertaken to determine indicators of early stages of biochemical damage (such as chromosomal aberrations) that would signal adverse health and genetic effects of ionizing radiation on human, plant and animal populations. Also, the impacts of ionizing radiation on the chemistry and microbial life of air, water and soil need to be researched [Comment 1750, Source Document phpub124, Page 3-35, Section 3]

OPG RESPONSE

OPG recognizes that ecological risk assessment (ERA) may become a more important component of the safety assessment of used fuel disposal in a geologic repository. For example, ERAs have been a required component of environmental impact statements for new uranium mines and decommissioning of old mines, and, more recently, environmental assessments of low and intermediate level waste facilities.

Ecological risk assessments of a single contaminant generally follow a relatively well-established methodology. However, the integration of the ecological effects of radioactive and chemical contaminants, and other potential stressors (e.g. habitat loss, temperature) within a single ERA framework is a new, emerging science and is not currently routinely done by industry. However, the CNSC is starting to ask for ERAs of multi-stressor effects and this issue is receiving increasing attention.

ERAs are site specific because they depend on the valued ecosystem components (e.g., rare species or food species) present near the proposed facility. When the time comes for the assessing the environmental impact of a geologic repository at a selected site, the most appropriate biosphere modelling methods for the conditions at the proposed repository site would be used both for ERA and the calculation of human exposure doses.

It is well known that the radiation dose-response relationship cannot automatically be assumed to be the same for humans and other species. The appropriate dose-response relationships would be used, if required, in any future safety assessment.

Radiological environmental assessment models like BIOTRAC, the EIS biosphere model, are difficult to validate because of the very low environmental nuclide concentrations and very long time periods. Hence, validation of such codes often involves comparison with similar but independently developed codes. "These intercomparisons enhance confidence in the results of biosphere analyses" (OECD/NEA Review Group 1995). As stated by the OECD/NEA Review Group (1995), the development of BIOTRAC "has availed itself of the international cooperation within the framework of the BIOMOVS program" (Garisto and Gierszewski 2001). OPG intends future involvement in these international code comparison exercises.

As noted by the SRG, many of the issues/questions concerning BIOTRAC are not important in terms of either the assessment of ultimate safety or the technical success of the concept and it would be

expensive to resolve these issues and questions. Furthermore, there is ongoing significant international effort in this area already. Therefore, for the present time, OPG intends to monitor the developments in the area of Ecological Risk Assessment, with emphasis on model improvements rather than on experimental data.

References

Garisto, F. and P. Gierszewski. 2001. Summary of verification and validation studies for SYVAC3-PR4 and its submodels. Ontario Power Generation Report 06819-REP-01200-10043-R00.

OECD/NEA Review Group. 1995. The disposal of Canada's nuclear fuel waste. Report of the OECD Nuclear Energy Agency Review Group. Submission to the Environmental Assessment Panel April 27. CEAA public file - TEC001.

7.03.05.06 Safety Assessment - Postclosure - Biosphere - Gaseous Radionuclides

PARTICIPANT COMMENTS

Scientific Review Group

The emanation of gaseous radionuclides 14C, 222Ra, 79Se, 129I, 81K, are considered in several places (R-Biosphere 1993: p.94,177,190), but in an incomplete manner. The calculations are for emissions only from soils, burning, etc., but do not flow in identified way from one sub-model to another.... Strangely, Se and I are not considered to be lost from shallow soils subjected to seasonal flooding (R-biosphere 1993: p.138); they are lost from open dry soils but do not infiltrate a house from the soils beneath it (R-Biosphere 1993: p.184). Some of these simplifications may be reasonable, and the apparent inconsistencies acceptable if they make model calculations easier, but they are further evidence of the subjective nature of BIOTRAC and the scenarios modelled.... A coherent modelling of the gaseous transfer is particularly important in light of the important role for human health over a period of 10,000 years of 129I and 14C (R-Biosphere 1993: p.330) [Comment 283, Source Document tec004, Page 235, Section H-2.3]

OPG RESPONSE

In the EIS, the local airborne concentrations from gaseous emissions from terrestrial and aquatic sources are calculated (Davis et al. 1993, p. 177). Airborne transport of nuclides from one location to another is not modelled in BIOTRAC (Davis et al. 1993, p.175). Rather these effects are accounted for implicitly by calculating air concentrations in a conservative way. Where a suspension mechanism is active over all fields, air concentrations over the most highly contaminated field is calculated in the usual way and it is assumed that the air over all the other fields is contaminated to the same extent. Where a suspension mechanism can occur over only one field, the air concentration for that field (and mechanism) is assumed to apply over all the fields. Thus, the total air concentration, which is the sum of contributions from all suspension mechanisms, is the same for any field.

For shallow soils, losses of nuclides from the soil compartment due to gaseous evasion are neglected (Davis et al. 1993, p.138). This is conservative because soil concentrations would be lower if losses due to gaseous evasion were taken into account. However, the nuclide air concentrations calculated in the EIS include contributions from gaseous evasion from shallow soils.

Except for radon, the infiltration of volatile nuclides into buildings (from soil) is not considered because estimates showed that the indoor air concentrations from this pathway would be much less than those predicted for release from domestic water for typical soil and water concentrations (Davis et al. p.184).

For simplification, many conservative assumptions have been made in the BIOTRAC model, e.g., although transport of airborne nuclides from field to field is not modelled, the airborne concentration over any field are taken to be the maximum concentration at any of the four fields. Thus, even though air transfer is not modelled explicitly, the potential effect of air transport on predicted airborne concentrations is implicitly accounted for by the conservative approach used in BIOTRAC.

References

Davis, P.A., R. Zach, M.E. Stephens, B.D. Amiro, G.A. Bird, J.A.K. Reid, M.I. Sheppard and M. Stephenson. 1993. The disposal of Canada's nuclear fuel waste: The biosphere model, BIOTRAC, for postclosure assessment. Atomic Energy of Canada Limited Report, AECL-10720.

7.03.05.07 Safety Assessment - Postclosure - Biosphere - Traits of the Critical Group

PARTICIPANT COMMENTS

Atomic Energy Control Board

The use of parameter "switches" to define traits of the critical group in the biosphere submodel is not shown to be appropriate.... Such traits should be set at the defined state resulting in the greatest consequence. In summary, exposure conditions related to the critical group's living habits and traits should not be treated as a variable or probabilistically. [Comment 581, Source Document gov002, Page 30, Section B.2.3]

OPG RESPONSE

Switches were used in the EIS postclosure assessment to determine the source of domestic water, to decide if the garden is irrigated, to determine the soil type and to determine the source of heating fuel (Goodwin et al. 1994, Figure 4-3). With this approach, critical groups having different characteristics could be investigated simultaneously in one probabilistic run.

In the EIS, the dose rates received by these "different" critical groups were not reported. Rather these dose rates were averaged to obtain an average overall dose rate. This procedure is potentially non-conservative because dose rates received by critical groups with potentially lower doses (those that use lake water) would be averaged with dose rates received by potentially more exposed critical groups (those that use well water).

However, whether or not this is acceptable depends on the difference in the dose rates for the "different" critical groups. According to ICRP60 recommendations (ICRP 1990), critical groups should be chosen to "be representative of individuals most highly exposed as a result of the source under review". They are required to be "reasonably homogeneous" with respect to the characteristics that influence their doses from that source. When this is achieved, mean exposure parameter values can be used to characterize critical group doses for comparison to dose limits. That is, if the effect of the switch parameter is minor then the averaging over this "switch" parameter would be valid. This is expected to be the case for the soil type "switch" parameter and the switch parameter defining the source of heating fuel. In any case, the appropriateness of averaging over the "different" critical groups.

In future, the sensitivity analyses can be used as a general test of whether any given switch should be used to define a different critical group. In the EIS Postclosure sensitivity analysis, only the median value case was examined in detail and the switches were fixed. However, the probabilistic sensitivity analysis in the SCS Postclosure report (Goodwin et al. 1996, Table 7) indicated that the source of drinking water switch was very important. It is expected that future safety assessments will consider separately the critical groups using the well as a water source, from those using the lake as water source.

References

Goodwin, B.W., D.B. McConnell, T.H. Andres, W.C. Hajas, D.M. LeNeveu, T.W. Melnyk, G.R. Sherman, M.E. Stephens, J.G. Szekely, P.C. Bera, C.M. Cosgrove, K.D. Dougan, S.B. Keeling, C.I. Kitson, B.C. Kummen, S.E. Oliver, K. Witzke, L. Wojciechowski and A.G. Wikjord. 1994. The disposal of Canada's nuclear fuel waste: Postclosure assessment of a reference system. Atomic Energy of Canada Limited Report AECL-10717.

Goodwin, B.W., T. Andres, W. Hajas, D. LeNeveu, T. Melnyk, J. Szekely, A. Wikjord, D. Donahue, S. Keeling, C. Kitson, S. Oliver, K. Witzke and L. Wojciechowski. 1996. The Disposal of Canada's Nuclear Fuel Waste: A study of postclosure safety of in-room emplacement of used CANDU fuel in

copper containers in permeable plutonic rock. Volume 5: Radiological Assessment. Atomic Energy of Canada Limited Report, AECL-11494-5, COG-95-552-5.

International Commission on Radiological Protection (ICRP). 1990. 1990 Recommendations of the International Commission on Radiological Protection. Publication 60. Pergamon Press.

7.03.05.08 Safety Assessment - Postclosure - Biosphere - Doses to Non-Human Biota

PARTICIPANT COMMENTS

Environment Canada

studies by the Environmental Advisory Team have shown that mistakes (i.e. overestimating by 103) have been made in the calculation of non-human doses during the postclosure period [Comment 858, Source Document gov003, Page 20, Section 2.9]

OPG RESPONSE

The animal dose rates reported in the EIS Postclosure report (Goodwin et al. 1994, p. 163) were overestimated by a factor of 1000. However, since the original calculated dose rates were very low, this error does not affect the EIS conclusions that doses to non-human biota, resulting from used fuel disposal, would be much smaller than background doses.

The error in the biosphere model was traced and has been corrected in the OPG safety assessment codes (SCC404 and later). The error affected the non-human doses from the water ingestion pathway and was due to a units conversion error.

References

Goodwin, B.W., D.B. McConnell, T.H. Andres, W.C. Hajas, D.M. LeNeveu, T.W. Melnyk, G.R. Sherman, M.E. Stephens, J.G. Szekely, P.C. Bera, C.M. Cosgrove, K.D. Dougan, S.B. Keeling, C.I. Kitson, B.C. Kummen, S.E. Oliver, K. Witzke, L. Wojciechowski and A.G. Wikjord. 1994. The disposal of Canada's nuclear fuel waste: Postclosure assessment of a reference system. Atomic Energy of Canada Limited Report AECL-10717.

7.03.06 Safety Assessment - Postclosure - Software Quality Assurance PARTICIPANT COMMENTS

Atomic Energy Control Board

While code development has been carried out at AECL in support of the EIS since the late 1970s, formal Software Quality Assurance processes have been put into use only recently. Of all the codes developed by AECL in support of the EIS, software quality assurance has been most stringent for SYVAC. However, the SYVAC Software Development Project Plan was approved for use in August 1993 and the Software Development Procedures in September 1994 (Allan, 1994), which in both cases was too late to be of any use.... Software quality assurance is generally lacking for the more-detailed computer codes upon which SYVAC is based. [Comment 660, Source Document gov002, Page 69, Section C.8.2]

In the configuration control and change request processes, two distinct steps, software deficiency reporting and corrective action, have been combined into one step, change request (Postclosure PRD, Figure B-1). Consequently, corrective actions can be decided upon, designed, and integrated into the model without sufficient review to determine what corrective action would be most effective. In addition there is no re-verification and re-validation, and no feedback to determine whether the deficiency has been adequately resolved. [Comment 661, Source Document gov002, Page 69, Section C.8.3]

Campaign for Nuclear Phaseout

There is no indication in the EIS that AECL's SYVAC has undergone a scientific review which is both comprehensive and independent. Such a review should be undertaken to determine if the programming methodology, models and data are deficient. [Comment 1808, Source Document pub027, Page 27, Section III.F]

Sailor, Ken

There must be an audit of the software to counteract natural self-interest and ensure the software's integrity. The audit should be performed by a panel of software experts with sufficient time and resources. The panel should

- be independent of the nuclear industry (to counteract self-interest)
- be able to establish criteria for success
- be funded

- be provided with access to necessary experts and documents. [Comment 1462, Source Document ph3pub047, Page 1]

Saskatchewan Environmental Society

In the matter of computer software supporting the important decision of how to dispose of nuclear fuel waste, we believe an independent audit is justified.... an independent team of experts, given the support of the principals involved, could perform a valuable service by verifying that to the best of their ability the software presented reasonable evidence that it functioned as specified and the reported results of the programs on their input data was correct. [Comment 1671, Source Document pub040, Page 09, Section 14]

Scientific Review Group

a summarizing timetable of enforcement of software quality assurance techniques and methodologies with time since the start of the model development should have been presented. Nine selected desirable software quality attributes are described but no comment is offered about how they were achieved. [Comment 174, Source Document tec004, Page 184, Section E-3.1]

The QA/QC program does not appear to be based upon a specific standard (such as International Standards Organization). [Comment 206, Source Document tec004, Page 192, Section E-5]

OPG RESPONSE

The SYVAC-CC3/PR4 models developed and used by AECL were subjected to a fair amount of internal quality assurance processes, including change control and verification, since the late 1980's, although this was not necessarily well documented at the time. Also, the formal CSA N286.7 standard for nuclear software was not issued until 1994, so there was no single reference standard.

There was in practice little changes in the codes after 1996, but there was considerable effort to improve the documentation of the codes. Also, after the codes were transferred to OPG, they were placed under NWMD software QA procedures that are based on the CSA N286.7-99 standard. Therefore, there should be a well-established QA trail for the main codes by the time they are to be used in any future safety assessment.

With respect to two specific comments:

#2. The NWMD configuration management and change control process is compatible with the CSA N286.7-99 standard.

#3,4,5. The desire for thorough review of the models is being addressed specifically as follows: - The EIS/SRG report was a reasonably complete review of the models. The comments from that review are reflected in this Comments database, and are being addressed through the ongoing NWMD work program.

- We have completed reviews of the SYVAC3-PR4 geosphere model, vault model and biosphere soil model.

- The current work program has started a continuing series of model validations.

- The need for an additional independent model review prior to a future licensing-related safety assessment will be reassessed closer to that time.

7.03.07 Safety Assessment - Postclosure - Input Data Quality Assurance PARTICIPANT COMMENTS

Atomic Energy Control Board

The data quality or data qualification process only focuses on the mechanics of entering data into the master database (Postclosure PRD, Section B.5.2). There are no quality assurance activities identified to control and determine the degree of validity of the data, such as calibration of instrumentation and verification/validation of data interpretation software. [Comment 662, Source Document gov002, Page 70, Section C.8.3]

Northwatch and Campaign for Nuclear Phaseout (Kreusch, Neumann, and Gruppe Ekologie)

Many input data are required for modelling the radionuclide migration. Whether the necessary data sets are actually representative and meaningful (i.e., regarding the geochemical situation) has to be proven. Sketchy data must be completed by tests. [Comment 1577, Source Document ph2tec044, Page 05, Section 2.2]

Scientific Review Group

Data on many aspects of biological processes in the southern part of the Canadian Shield are sparse and of doubtful representativeness.... expert judgement makes the final predictions more subjective, and less directly supported by firm data or knowledge of environmental processes. These judgements should have been made and documented following standard protocol. [Comment 420, Source Document tec004, Page 069, Section 6.4.2]

OPG RESPONSE

The input data quality will be addressed by:

- requiring that relevant measurements be carried out to appropriate standards, such as ISO 9000 (presently part of the OPG contract requirements);

- control and documentation of the data once it is accepted into the OPG reference dataset;
- ongoing testing of the model using the datasets;
- research, and data sharing with other organizations, to improve the database.

The sensitivity study performed in the EIS and SCS reports indicates which parameters have a larger influence on the results, and therefore provided a priorities for the present work program - e.g., the insitu diffusivity program at AECL URL which examined the tortuosity of sparsely-fractured rock, and the I-129 biosphere review (Sheppard et al. 2002). Ongoing activities to analyze other case studies (e.g. SR97 simulation in 2000/2001) provide further opportunities to identify key parameters.

All the EIS/SCS parameters in the reference database were recently internally reviewed as part of OPG preparation for a Third Case Study exercise. This review checked that database values were as stated in the EIS/SCS documentation (or others, as appropriate). Further review of the data is planned, including comparison with the reference biosphere values recently accepted by CNSC for use in Derived Release Limit calculations (BEAK 2002).

References:

BEAK. 2002. Guidance for calculations of Derived Release Limits for radionuclides in airborne and liquid effluents from Ontario Power Generation nuclear facilities. OPG report N-REP-03482-10000-R00.

M. Sheppard et al. 2002. Recommended biosphere model values for iodine. OPG report 06819-REP-01200-10090.

7.03.08 Safety Assessment - Postclosure - Uncertainty

PARTICIPANT COMMENTS

Canadian Voice of Women for Peace

Another important facet of the incredible lack of safety of the concept is the limitation of current technical and scientific knowledge and the inherent inability of simulations to predict very complex interactions over very long periods of time. [Comment 1918, Source Document cs023, Page 2]

Environment Canada

It is not clear that process uncertainty and model-related uncertainty are adequately considered in BIOTRAC or in SYVAC3. [Comment 884, Source Document gov003, Page 30, Section 2.14]

Health Canada

In the Biosphere primary reference, it is stated that, while some of the assumptions may result in overestimation, others may result in under-estimation. This has not been quantified, or included in the estimate of overall error on the modelled dose. [Comment 952, Source Document gov006, Page 14]

the EIS should give a best estimate of uncertainty associated with inherent limitations of the generic models, and the generic parameter distributions. [Comment 953, Source Document gov006, Page 15]

The EIS does not discuss the degree of uncertainty associated with the choice of parameter range or median value.... How is the degree of uncertainty to be reduced for site--specific applications? [Comment 954, Source Document gov006, Page 15]

there is no estimate of the best accuracy that can be expected in the model predictions, taking into consideration the uncertainty in parameter ranges, and the simplifying assumptions used in the development of the models. [Comment 956, Source Document gov006, Page 16]

Uncertainties in model outputs, over and above probability distributions of input parameters, should be discussed. [Comment 968, Source Document gov006, Page 18]

The report stresses the quantity of estimates produced, where one would look for claims of careful selection to ensure quality. Predicted mean dose rates and risks of health effects across time are modelled, though no discussion of the uncertainties is presented. [Comment 977, Source Document gov006, Page 23]

little is made of the variability of the estimates throughout the text ... The philosophy of the discussion appears to be a desire to eliminate variability, and not a careful consideration of measurement of variability and use of this in making inferences. [Comment 979, Source Document gov006, Page 23]

The generic biosphere and food-chain models contain many parameters for which data is not well known, and have therefore been based on limited experimental data or through analogy with other parameters. The effect of this uncertainty on radiation dose has not been sufficiently addressed. [Comment 990, Source Document ph2gov011, Page 07]

National Action Committee on the Status of Women

Very little discussion of the debate or the uncertainties, assumptions and value judgements surrounding the risk assessment process occurs in the EIS [Comment 1309, Source Document pub026, Page 50, Section 7.7.2]

Northumberland Environmental Protection

The AECL case studies come up with safety margins of 10/6 for the first TITANIUM case: 10\2 for the COPPER CASE. But the uncertainties could be many orders of magnitude larger than these values: we estimate they could easily be in the region of 10\10. [Comment 1504, Source Document cs028, Page 1]

the prevailing uncertainty and difference between specific localities within a site are greater than the difference between sites or even between rock types. The inhomogeneity is at small-scale level, not simply at macro site-level. The problem with modelling arises, not so much because of differences BETWEEN sites, but because of the inhomegeneity within ANY SPECIFIC SITE. [Comment 1509, Source Document cs028, Page 3]

At another level the real problem with modelling arises because many of the interactions discussed are taking place at unmodellable micro-environmental level, through localized non uniform processes. It is important to point out that all the other difficulties that arise with respect to generic modelling and assessment will also arise with site specific. The problems of loss of bentonite integrity, microbial induced corrosion, copper pitting, redox potential under the unknown emerging conditions and influences, hydrogen gas generation, are all unknown mechanisms. [Comment 1510, Source Document cs028, Page 3]

CAN IMPACTS BE PREDICTED 10,000 YEARS HENCE? Anyone with half a grasp about the pace of change being wrought, in the world and on the world, will know that they can't. [Comment 1329, Source Document ph2pub010b, Page 01]

The test of the FIRST SUBMISSION, supported the assertion that the reason why the AECL researchers do not succeed in the endeavour to model a generic postclosure assessment impacting over 10,000 years, is because they do not have, and cannot get the relevant data with regard to the prevailing uncertainty of burial in rock. To this we must add, nor do the AECL have the power of prediction into an unknown alterable future. This unsolvable fundamental problem obvious applies to assessment of the disposal concept at any level, GENERIC or SITE SPECIFIC. [Comment 1330, Source Document ph2pub010b, Page 01]

Northwatch and Campaign for Nuclear Phaseout (Kreusch, Neumann, and Gruppe Ekologie)

There are fundamental problems with the modelling methodology used in long term safety analysis. This is because, inevitably, there is insufficient knowledge about the repository system, and because very long term prognoses are necessary. The predictive power of computer modelling (deterministic and probabilistic modelling) used in long term safety assessment is greatly overrated at present. It is therefore a matter of urgency that their relevance to the qualification procedure is put into perspective. [Comment 1587, Source Document ph2tec044, Page 16, Section 5]

Because the results of safety analyses (especially model calculations) are oriented according to dose limitation values, the range of uncertainty of such model calculations must be taken into account (e.g. in the form of a safety factor). [Comment 1588, Source Document ph2tec044, Page 17, Section 5]

the computer modelling must be based on a databasis containing sufficient qualitative and quantitative information. It must provide a model of the radionuclide transport process which approaches reality. Bridging inevitable gaps in the information with conservative assumptions, can be no replacement for the careful and wide ranging collation of data [Comment 1589, Source Document ph2tec044, Page 18, Section 6]

Nuclear Awareness Project

AECL should fully report on areas where scientific opinion differs on matters concerning used nuclear fuel disposal [Comment 1607, Source Document pub035, Page 5, Section D]

OECD/NEA Review Group

The convolution of different types of uncertainty, variability and scenario probabilities into SYVAC runs can lead to a lack of transparency in the analyses of behaviour of the disposal system. [Comment 1225, Source Document tec001, Page 13, Section 4.2]

Transparency and ability to interpret and unfold the results are masked by the mixture of conservative, mean and probabilistic assumptions and presentations. It ought to be made clearer and defended that what is presented is the modelled system variability in a conservative framework. [Comment 1230, Source Document tec001, Page 14, Section 4.3]

Robertson, J.A.L.

An important aspect of uncertainty is missing from the discussion. For the assessment in the EIS some of the input has had to be appropriate for anywhere in Ontario's part of the Canadian Shield, resulting in much of the uncertainty. When actual sites are considered in the site-selection process it will be possible to narrow the ranges in the input, and hence reduce the uncertainty. [Comment 1450, Source Document phpub004, Page 10]

The EIS provides a fair estimate of the current uncertainties in calculations of radiation doses, and hence risks, to future generations (Chapter 7 of AECL-10711). However, 7.14 Treatment of Uncertainty in Postclosure Assessment does not adequately distinguish between those uncertainities that will be reduced or eliminated when information is available on actual sites and those that will still remain.... the level of uncertainty is likely to be less in an EIS proposing the implementation of the concept on an actual site than in this EIS for concept assessment. [Comment 1461, Source Document phpub004, Page 34]

Saskatchewan Environmental Society

the EIS cannot be convincing, because the complexity of the issues it deals with is beyond our capacity to reliably forecast. [Comment 1683, Source Document ph2pub006, Page 4]

Scientific Review Group

SYVAC's probabilistic framework does not account for biases and uncertainties in the model structure, or for incorrect hypotheses and assumptions that may lead to biases. Large numbers of parameters are analyzed probabilistically, but the most important amongst these, namely those that control groundwater flow, are excluded from the probabilistic analysis, apparently because the SYVAC structure requires a fixed network of flowpaths. Thus the analysis may be driven by the constraints of the model [Comment 430, Source Document tec004, Page 074, Section 6.5.5]

The postclosure assessment does not adequately account for biases and uncertainties, nor is it inherently conservative. AECL has claimed that the effects of unknown processes, systematic measurement error, assumption errors, and programming and data errors as well as natural variability, time-varying processes and random measurement error can be dealt with by using parameter density distributions (PDFs) and switches. This claim is not valid because: (1) errors in model structure lead to bias which can seldom be predicted; (2) transport paths in the vault and geosphere are not allowed to vary; (3) median value simulations may not identify processes important in producing the highest doses; (4) SRG analysis has shown that several parameters that are supposed to be conservative are not; (5) some PDFs are unreliable; and, (6) arbitrary upper/lower limits are set on some parameters. [Comment 135, Source Document tec004, Page 154, Section E-S]

There are several problems with using PDFs to account for uncertainty in model structure. Errors in model structure invariably lead not only to increase uncertainty (as represented by broader PDF curves) but to bias (a systematic shift in the PDF curve). This shift can seldom be predicted (and is not mentioned in R-Postclosure).... In some cases, processes that were not explicitly part of a conceptual model were implicitly considered through sampling of PDF extremes. However, during sensitivity analysis, deterministic analysis using median value simulations would miss identifying these processes as important. Thus, the conceptual model uncertainty is still not addressed in a transparent manner [Comment 166, Source Document tec004, Page 183, Section E-3.1]

Because the four main sources of uncertainty (natural variability, parameter uncertainty, conceptual model uncertainty and computational uncertainty) were lumped together into the PDFs it is impossible to evaluate the individual contribution of each of these errors or uncertainties in the final results. [Comment 193, Source Document tec004, Page 190, Section E-4]

The treatment of uncertainty is unsatisfactory because there was no clear distinction made between parameter and model uncertainty. Furthermore, bias was not discussed and pathways with large uncertainties were frozen in the vault and geosphere models thus ignoring uncertainty in these travel paths. [Comment 200, Source Document tec004, Page 191, Section E-5]

OPG RESPONSE

We do not expect that a meaningful quantitative measure of overall uncertainty in the results can be developed. However, there are some approaches that can be used to help assess the overall uncertainty and its importance.

First, ongoing testing of the models will also provide some quantification of the uncertainty with respect to specific processes or conditions.

Second, confidence in the results will be approached in a future safety assessment by providing multiple lines of reasoning (e.g. measurements of groundwater age at depth at a specific site), use of simple bounding models, and explicit analysis of "what if" scenarios.

Thirdly, it is expected that future safety assessments will attempt to distinguish between, and discuss better, the different types of uncertainties. For example, the use different conceptual models (e.g., different geosphere, different system models) would provide some information on the conceptual model uncertainties. Or the detailed 3-D models could be used for specific cases could provide information on the importance of spatial heterogeneity. As a specific point, the uncertainty in groundwater flow regimes would be treated differently in future assessments.

Finally, some parameter uncertainties (e.g. soil type, rainfall rates), and possibly model uncertainties, will decrease after a repository site has been selected.

7.03.09 Safety Assessment - Postclosure - Verification and Validation PARTICIPANT COMMENTS

Atomic Energy Control Board

The testing of many of the models underlying the development of the SYVAC3-CC3 simulation models is not consistent, especially the criteria for judging the testing. [Comment 664, Source Document gov002, Page 70, Section C.8.5]

the testing of key aspects of SYVAC was not complete at the time of the release of the EIS. For example, independent unit verification tests of vault model modules were not completed (Vault PRD, Section 7.4.2). [Comment 666, Source Document gov002, Page 70, Section C.8.5]

Campaign for Nuclear Phaseout

Plutonic rocks, ... are among the least studied kinds of rocks.... the scanty data we have about plutonic rocks are fed into the computer simulation models that are meant to describe the conditions around the repository in x thousand years.... The mathematical models into which such limited data are being fed into, need to be verified, ... So in order to verify the models that are used to make the predictions on the safety of the proposed repository, one needs to run experiments that last several thousand when not several million years. The proponent has failed do do this. [Comment 1830, Source Document phpub104, Page 02]

AECL must clearly demonstrate the methodology used for model validation. This methodology must be subject to independent (non-AECL/nuclear industry funded) peer review.... [include] the differences of opinion in the scientific community about AECL's work. [Comment 1790, Source Document pub027, Page 23, Section III.C]

One of the questions that needs to be examined is whether the mathematical models which serve as the basis for the EIS are reproducible. Models which are not reproducible and thus not accountable, leave room for uncontested analysis. This can lead to analytical frameworks which in addition to underestimating environmental impacts, are biased in a manner which implicitly supports particular socio-economic or political frameworks. [Comment 1806, Source Document pub027, Page 26, Section III.F]

the EIS has not outlined the criteria for deciding what constitutes sufficient validation. [Comment 1807, Source Document pub027, Page 27, Section III.F]

Canadian Coalition for Nuclear Responsibility (Regroupement pour la surveillance du nucléaire)

Probabilistic methods in geology are still quite new, and most of the probability models used to predict post-closure behaviour of the repository have not been validated against reality. [Comment 1908, Source Document cs031, Page 03]

The proponent has a moral and ethical obligation to explain both the strengths and weaknesses of computerized mathematical models, and to illuminate the technical meanings of the words validation & verification. [Comment 1888, Source Document pub049, Page 30]

The proponent should explain clearly why it is so difficult to validate all of the mathematical models that are used in the post-closure assessment. The proponent should also attempt to define what level of certitude we can hope to accomplish, and suggest an objective criterion to be used for deciding to accept the prediction or to reject it. [Comment 1893, Source Document pub049, Page 36]

Canadian Geoscience Council

The Syvac modeling probabilistic systems analysis is a highly necessary stage in integrating the various components studies into a yes or no value judgement on level of performance. Heavy effort was invested on demonstrations of its procedural correctness and probably not nearly enough on verifying the reliability and significance of the parameters and simplified models that go into any SYVAC run. [Comment 1053, Source Document tec002, Page 21, Section 3.4.2]

Environment Canada

we consider the discussion of the validation and verification of SYVAC3 to be insufficient to credibly demonstrate the safety and acceptability of AECL's disposal concept. [Comment 860, Source Document gov003, Page 20, Section 2.9]

With respect to postclosure, the lack of a clear definition of model validation represents a minor deficiency in the EIS documentation that can be remedied by appropriate description and referencing of validation studies. [Comment 893, Source Document gov003, Page 36, Section 2.16]

Health Canada

The EIS does not discuss the criteria to be used in deciding what constitutes sufficient validation. [Comment 955, Source Document gov006, Page 15]

Given the complexity of the model and the very large number of different physical situations, one misses the validation along the lines presented in section 6.3 of the Guidelines or evidence of external review of the methods. [Comment 976, Source Document gov006, Page 22]

It is difficult to determine how black the modelling box is, there is little evidence of model validation, external review or the use of uncertainties in making predictions. [Comment 980, Source Document gov006, Page 25]

Joint Committee of the Canadian Academy of Engineering and the Royal Society of Canada

The SYVAC models were used to estimate radiological dose rates to individuals in critical groups under a very large number of physical situations in the post-closure phase (Ref. 1 p.296). The complexity of these models and the accompanying codes make evaluation of their results difficult to those not involved with their design and operation.... To partially validate these global models, a series of more circumscribed process models would be desirable, each checked for its fit with available empirical data on some aspect of the overall problem. We note with some concern that this has been done to a limited degree only, and with limited success. [Comment 1165, Source Document ph2tec007, Page 11]

Mouvement Vert - Mauricie

The MVM would like the proponent to clearly present the hypotheses used in formulating its models and identify which components can be considered validated. A plan should also be presented that covers the field tests to validate the models developed. [Comment 1492, Source Document pub024, Page 32, Section 2.4.5]

the proponent should provide evidence that its approach, based on data generated by probability distribution, is acceptable for a geological application.... It seems possible that the geological systems may react in a chaotic manner, i.e. minor changes in their initial conditions or natural parameters, such as porosity or the hydrographic regime, would lead to major differences in the system's responses. [Comment 1493, Source Document pub024, Page 32, Section 2.4.5]

Northwatch

the EIS should provide proof that their models are valid [Comment 1372, Source Document pub046, Page 15, Section d]

the EIS should include a criteria for validation of the models used; limitations of the models should be clearly discussed [Comment 1375, Source Document pub046, Page 15, Section d]

the EIS does not include adequate discussion of the determination of parameters or model validation; [Comment 1379, Source Document pub046, Page 15, Section d]

Northwatch and Campaign for Nuclear Phaseout (Kreusch, Neumann, and Gruppe Ekologie)

Models cannot be used as part of a long-term safety analysis without verification and validation. Based on our knowledge, the used models are not validated. The consequence of a missing model validation is that the calculated dose rates are at most coincidentally related to the expected actual situation in the future. This is also true for the probabilistic methodology used by AECL. [Comment 1574, Source Document ph2tec044, Page 05, Section 2.2]

clear regulations [are needed] for planning and using computer models in safety analyses, and for qualifying (verifying and validating) the models used. [Comment 1590, Source Document ph2tec044, Page 18, Section 6]

OECD/NEA Review Group

detailed reconciliation of the extensive and high-quality suite of hydrochemical observations with groundwater flow models in the Whiteshell Research Area is not currently very advanced and the information used to support the Reference Case analysis was quite limited. The use of hydrogeochemistry for 'validation' of time-dependent groundwater flow models using palaeohydrogeological techniques is an important area which could be investigated further in future. [Comment 1215, Source Document tec001, Page 10, Section 3.2.2]

Robertson, J.A.L.

There is a ... desire on the part of the public for a demonstration of geological predictions, e.g., the time taken for contaminants to travel through flaws in the rock. Here, the EIS could have done more to examine the feasibility of limited demonstrations, possibly by injecting a dye or a short-lived radioisotope into a research site for which predictions had been made. [Comment 1449, Source Document phpub004, Page 10]

Saskatchewan Environmental Society

A great majority of the evidence presented by AECL to prove its long-term predictions to validate its concept is purely speculative and highly mathematical with a minimum of practical verification. [Comment 1710, Source Document ph3pub014, Page 2]

Scientific Review Group

AECL has made a credible effort to surmount the impossible hurdle of validation of a model system that must extend to 10,000 years in the future. However, its intent is violated throughout the analysis by the adoption of non-conservative assumptions. A comprehensive analysis of any factors that might compromise the long-term integrity of the waste exclusion zone (which emerges from the analysis as the single most important factor in the safety of the concept) would have increased credibility. [Comment 207, Source Document tec004, Page 192, Section E-5]

AECL used a series of comparisons with models developed by other groups at the national and international level to evaluate the models used in the SYVAC3-CC3 system model. While the AECL models have performed well in these comparisons, the SRG notes that such evaluations should not be confused with comparisons of observations of real systems. [Comment 208, Source Document tec004, Page 192, Section E-5]

The use of the term validation in this document may be misleading... AECL appears to have placed unwarranted emphasis on verification, and to have been overoptimistic in claiming validation of MOTIF, within SYVAC3-CC3. [Comment 521, Source Document tec004, Page 220, Section G-3.2.9]

OPG RESPONSE

The comments generally indicate that model verification was adequately achieved but question the extent of validation.

With respect to verification, note that the AECL internal QA process for code development included a substantial degree of undocumented verification. Since the codes were transferred to OPG in 1996, there has been a fair amount of effort to document the models better, including further verification. Also, all subsequent model changes are made under a change control process that is compliant with CSA N286.7-99.

With respect to validation, as noted in the EIS report (Postclosure report, p.348), full validation of a used fuel disposal system model is not possible due to the long time scales involved. The AECB/CNSC R-104 Regulatory Policy Statement (AECB, 1987) also recognizes that the results of the predictive modelling will be approximate, and confidence in the modelling output must come from a combination of several complementary methods of examining the models and results. It is not expected that a firm quantitative criterion can be specified to judge whether the overall system model is valid or not. Rather, the planned process is to undertake (and publish for peer review) a continuous program of testing of the models. This recognizes that each test case provides a limited test on its own, but each contributes to continually improve our confidence in the overall model results. In addition, a future safety assessment would use multiple lines of reasoning, such as the measured age of the groundwater and natural analogs, in order to provide additional arguments for the safety of a repository.

Specific recent reports on the validation of the main models are:

Goodwin, B. et al. 2002. Validation of four submodels of SYVAC3-CC4, Version SCC402. Ontario Power Generation report 06819-REP-01300-10057-R00.

Garisto F. and P. Gierszewski. 2001. Summary of verification and validation studies for SYVAC3-PR4 and its submodels. Ontario Power Generation report 06819-REP-01200-10043-R00.

Garisto, F., P. Gierszewski, A. D'Andrea and M. Da Silva. 2001. Simulations of the SR97 safety assessment case using the NUCTRAN, RSM, DSM and PR4 codes. Ontario Power Generation report 06819-REP-01200-10057-R00.

Garisto, F., P. Gierszewski, B. Goodwin and A. D'Andrea. 2000. Radionuclide Screening Model (RSM) Version 1.0 validation. Ontario Power Generation report 06819-REP-01300-10001-R00.

Chan, T., N. Scheier and F. Stanchell. 2000. MOTIF Version 3.2 Verification and validation report. Ontario Power Generation report 06819-REP-01200-10026-R00.

7.03.10 Safety Assessment - Postclosure - Probability Density Functions PARTICIPANT COMMENTS

Atomic Energy Control Board

In the description of the data used in the modelling in the Postclosure PRD (p. 126), it is not clear how correlations are handled mathematically in SYVAC. In addition, it should be recognized that selecting the attributes of an input pdf to bias the results to overestimate the impact (Postclosure PRD, p. 128) is possible only if the response spectrum of the model to that parameter is known. This has only been investigated in a limited sense (in the sensitivity analyses), and there is no indication that the sensitivities have been used to define the input pdfs or to determine which processes and mechanisms to include. [Comment 591, Source Document gov002, Page 36, Section B.4.1]

Environment Canada

Other issues identified as being of concern were: ... inadequate support for the parameters assigned to the probability density functions [Comment 876, Source Document gov003, Page 27, Section 2.13]

Health Canada

the mean value of each PDF reflects current conditions, and influences the probability of a specific value being sampled during the probabilistic simulation of the model. Under conditions of climate change or other long-term phenomena, the variation in a parameter may be better reflected by a distribution with a different mean. [Comment 950, Source Document gov006, Page 14]

Since parameter PDFs account for the likelihood of occurrence of specific values of the parameter, what uncertainties are associated with a shift in the mean of these distributions as a result of long-term changes, and therefore of the likelihood of occurrence of a specific value? [Comment 958, Source Document gov006, Page 16]

Natural Resources Canada

Some quantitative estimates seem to be arbitrarily introduced.... There is no mention of data source or how the estimates were reached. In this example, as in others, the parameter is said to be lognormally distributed ... No information is given on the variable against which it is lognormally distributed. [Comment 714, Source Document ph2gov001, Page bio2]

Scientific Review Group

The derivation of the PDFs is very important. It should have been (but was not) thoroughly documented, transparent, and subject to revision with improvements in observations and scientific understanding. [Comment 448, Source Document tec004, Page 081, Section 6.6.3]

the PDFs that were used merit a close scrutiny because they have a sizeable influence on the final outcome [Comment 165, Source Document tec004, Page 182, Section E-3.1]

Because the PDFs that were used have a considerable influence on the outcome, the influence of different PDF distribution types should have been examined more closely and the justification for the shape of the PDFs used should have been more clear. [Comment 195, Source Document tec004, Page 190, Section E-4]

The critical importance of the PDFs ... produces concern regarding the validity of the PDFs and the transparency of the process that led to the development of the PDFs. [Comment 205, Source Document tec004, Page 191, Section E-5]

Reliance is placed on probability density functions to account for variations on time scales greater than one year (R-Biosphere 1993: p.53). This is a scientifically questionable procedure for accommodating changes or trends over ten thousand years. [Comment 268, Source Document tec004, Page 232, Section H-2.3]

OPG RESPONSE

In general, we prefer to use best estimate PDFs, rather than "conservative" PDFs. It is for those cases where data are particularly scarce, or values are likely unimportant, that we may use conservative PDF ranges. We recognize that it may not always be obvious how to bias a given PDF to be conservative, but in specific cases it can be verified by testing.

The database is presently archived and controlled as part of our software QA system. For the present OPG Third Case Study exercise, we will be issuing a separate report with a complete list of all the data (and PDFs) and their justification (e.g. references). This will make the present PDF basis more transparent.

As we develop new information, we are updating our PDFs. We are focussing on the more important parameters, which we determine from the results of sensitivity studies, from understanding of physical processes, and from review of other international studies. For example, results of the EIS/SCS postclosure dose results and sensitivity studies indicated that I-129 in general, and some of its biosphere parameters in particular, were important contributors to both dose and to sensitivity in dose results. Therefore, we have recently completed a review of the biosphere iodine parameter PDFs (Sheppard et al. 2002), and have updated the database PDFs according to this review.

Some comments (#3,#10) question whether a PDF can be used to adequately cover time-dependent effects. This is expected to be a reasonable approximation for processes that reach equilibrium relatively quickly (e.g., EIS Biosphere report, p.53). The applicability of this approach in general is addressed in part through validation tests, through results from the detailed supporting models (eg. Glaciation models), and through selection of suitable range of scenarios in the safety assessment itself. The possibility of adding time-dependence to the model itself also is being considered. These need to be more explicitly considered in future safety assessments.

Comment #1 also asks how correlations are handled mathematically in SYVAC. This information is given in Andres (1995).

References

Andres, T. 1995. SYVAC3 parameter distribution package. AECL-10983.

7.03.11 Safety Assessment - Postclosure - Monte Carlo PARTICIPANT COMMENTS

Atomic Energy Control Board

SYVAC is not an appropriate tool to perform a complete risk analysis.... SYVAC3-CC3 predictions, then, should be considered a joint conditional distribution of possible outcomes, with no significance implied by the frequency of calculating a value.... Since conceptual models are mutually exclusive, SYVAC3-CC3 is not appropriate for integrating disparate models to examine conceptual model uncertainty. Furthermore, multiplying the frequency of a calculation by its consequence is not an estimate of risk. [Comment 577, Source Document gov002, Page 28, Section B.2.1]

The probabilistic approach embodied in SYVAC has not been independently reviewed by experts in mathematical statistics. As a result, there is no assurance that the uncertainties associated with imprecise knowledge of the future behaviour of the engineered and natural systems are being adequately incorporated in model predictions (Postclosure PRD, Section 2.5). [Comment 663, Source Document gov002, Page 70, Section C.8.4]

OECD/NEA Review Group

Given the central role of SYVAC in the analyses, some discussion of the advantages and disadvantages of the approach (as opposed to a more discretised approach using scenario and consequence analysis) would have been valuable in the documentation. [Comment 1223, Source Document tec001, Page 13, Section 4.2]

Confidence in the convergence of the SYVAC results when only 40,000 runs were carried out will eventually need to be further supported, e.g., by case studies with an order of magnitude more runs. [Comment 1232, Source Document tec001, Page 14, Section 4.3]

Scientific Review Group

Monte Carlo simulations, by the compounding effect of many computational approximations, may sometimes lead to misleading results [Comment 327, Source Document tec004, Page 027, Section 4.4.2]

not enough attention has been paid to current literature on experimental design of Monte Carlo type probabilistic simulation experiments ... The number of samples used in the probabilistic analysis was apparently too small for comprehensive statistical manipulation and some of the statistical tools used were not ideally suited to the job ... There is a danger of obtaining unreliable results with Monte Carlo simulations. Two main problems are: (1) the lack of a mathematical relation between the error as measured by comparing results of consecutive computations and the real error as measured by comparing the results with an analytical solution; (2) the great number of samples needed for reaching a reasonable accuracy often implies that the model will have to accurately handle sets of very large numbers of about the same order of magnitude. [Comment 171, Source Document tec004, Page 184, Section E-3.1]

OPG RESPONSE

See the comments under 7.03.13.01 It is intended to review the basis for how the probabilistic results should be generated and analyzed.

7.03.12 Safety Assessment - Postclosure - Median Value Simulations PARTICIPANT COMMENTS

Atomic Energy Control Board

The sensitivities of maximum annual dose to well demand and depth in the median-value simulation in the Postclosure PRD are somewhat misleading, as only one parameter is varied at a time. As such, the sensitivities may not reflect the potential for a deep, communal well to capture the majority of the contaminants released without excessive dilution ... For higher pumping rates, maximum doses may increase with increasing well depth.... for well depths greater than about 100 m ... dose may increase with the number of people in the critical group. [Comment 654, Source Document gov002, Page 64, Section C.6.1]

Northumberland Environmental Protection (Fairlie)

The assumption, in the median value case, of low U02 release rates of the order of .00000001 applies of course to all other nuclides trapped in the uranium fuel ceramic. This fact combined with the 100,000 year cutoff in the analyses means there is little discussion of fates of long-lived actinides in fuel : [Comment 1342, Source Document ph2tec006, Page 04]

OECD/NEA Review Group

It is useful to have a deterministic calculation to compare with the PSA results, but it is not obvious why AECL chose the median value to present the results. There is no parallel easy way to compare the mean values of probabilistic calculations and results of deterministic calculations with mean value parameters. It would, thus, have been instructive to look at outlying, high-consequence deterministic results and to discuss the circumstances under which they might arise. [Comment 1229, Source Document tec001, Page 14, Section 4.3]

Scientific Review Group

The rationale for using the median value and not the arithmetic mean of PDFs is not fully explained. The median value is central but not necessarily representative of the weight of the distribution. Median value simulations ignore processes not explicitly included in components of the system model but which could be considered implicitly through the sampling of PDF extremes. Such processes can never be identified as significant since they would not be included in median-value simulations. [Comment 177, Source Document tec004, Page 185, Section E-3.1]

Circular reasoning is displayed with respect to the implicit treatment of certain processes. Processes that were implicitly included by sampling from the full range of PDFs may not have been represented in the median value simulations; yet, these median value simulations were used to identify important features and processes. Therefore, the prior judgement that resulted in certain processes being excluded from explicit treatment was not tested. [Comment 201, Source Document tec004, Page 191, Section E-5]

Median value simulations are not representative of the weight of parameter distributions. [Comment 202, Source Document tec004, Page 191, Section E-5]

OPG RESPONSE

These comments essentially focus on the appropriateness of the median value simulation as a reference case, and in particular its usefulness with respect to sensitivity analyses.

It seems doubtful that any single sensitivity analysis could provide all the information desired, and in fact the EIS included both sensitivity analyses of the median value simulation and of the probabilistic simulations. For future safety assessments, additional analysis of more "what if" scenarios or high-consequence scenarios, and of the sensitivity of the probabilistic results, should help put the Median

Value Simulation results into perspective as simply another way of looking at the results to see if they make sense.

7.03.13 Safety Assessment - Postclosure - Analysis of Results

7.03.13.01 Safety Assessment - Postclosure - Analysis of Results - Statistical PARTICIPANT COMMENTS

Natural Resources Canada

In this section the authors show that univariate statistics from the SVA simulations converge towards theoretical values. However, for completeness, they should show that bivariate statistics such as correlation coefficients also converge towards specified values. [Comment 781, Source Document ph2gov001, Page pos5]

Scientific Review Group

some of the statistical tools and treatments used in the probabilistic analysis were inappropriate or not ideally suited to the task and could have contributed to unreliable or misleading output. For example, AECL has assumed that means, variance, and confidence limits could be produced from the output of the probabilistic simulations using classical statistical calculations. This assumption was based upon the central limit theorem, which states that as sample size increases, the means of samples drawn from a population of any distribution will approach the normal distribution ... However, the number of simulation runs may have been too small to fulfill the central limit theorem requirements. AECL should have used alternative sampling techniques such as the bookstrap method to address this issue [Comment 457, Source Document tec004, Page 084, Section 6.6.5]

The massive output should have been amenable to a much more extensive statistical analysis (variance, covariance, skewness, kurtosis) and output probability distributions, individual as well as joint. This, in turn could have been used to quantify the variability of releases about their mean and median values and to compute the probability of meeting or not meeting AECB or other criteria at various times. [Comment 168, Source Document tec004, Page 183, Section E-3.1]

The statistical methods used to evaluate the results that were obtained, and to calculate confidence bounds, is a source of concern. ... a general sampling formula could be applied to determine the number of samples needed to obtain an estimate that lies within a specified interval at a particular confidence level. [Comment 172, Source Document tec004, Page 184, Section E-3.1]

AECL would have benefited from setting an Acceptable Quality Level (AQL) (the maximum percentage of unacceptable items that can be tolerated in a random sample of 100) based upon ISO-2859. These AQLs can then be used to asses the number of doses above a certain level that can be tolerated. [Comment 173, Source Document tec004, Page 184, Section E-3.1]

Caution is required in presentation of the probabilistic analyses because many more samples are needed to produce statistically reliable results.... Furthermore, the reliability of the calculated probabilities associated with maximum doses depends upon the number of simulations. [Comment 192, Source Document tec004, Page 190, Section E-4]

OPG RESPONSE

It is not clear that there is a single right way to statistically analyze the results of the probabilistic calculations. However, OPG will consult with relevant experts to determine a reasonable path forward for conducting and analyzing any future probabilistic safety assessments. It should also be noted, however, that we expect that future safety assessments will place less weight on the results of a single massive probabilistic analysis, and therefore there will be less emphasis on statistical analyses.

PARTICIPANT COMMENTS

7.03.13.02

Atomic Energy Control Board

Analysis

The sensitivity analysis of the postclosure predictive models is misleading and of questionable value.... The parameter sensitivities in the systems model, then, do not necessarily reflect the mechanistic relationships or correlations amongst processes and parameters that the detailed models attempt to simulate.... It is ... not clear whether the screening methods will adequately examine calculated parameters that can be measured experimentally, such as apparent diffusion coefficient.... None of the sensitivities or derived constraints that are examined consider the impact of failure of any of the barriers, with the exception of the container (such as cracking the waste exclusion zone or bypassing the backfill). The results of the sensitivity studies are not discussed adequately.... The three design constraints that are identified (keep waste below fracture zone, enlarge waste exclusion zone and increase container lifetime: Postclosure PRD, p. xxi) all reduce the dose at 105 years by less than one order of magnitude, which is much less than the uncertainty in the predictions. [Comment 592, Source Document gov002, Page 37, Section B.4.2]

Environment Canada

there is also concern about ... the fact that the sensitivity analysis in the EIS does not assess the behaviour of the hydrogeological system when the permeability of sparsely-fractured rock is more than one order of magnitude greater than that chosen by AECL as the expected value. [Comment 857, Source Document gov003, Page 20, Section 2.9]

Health Canada

The sensitivity of model estimates to tortuosity of the lower rock zone and use of well-water are noted.... The next most critical factors are not discussed, nor any mention of whether the model is a little or much less sensitive to the next factor. [Comment 978, Source Document gov006, Page 23]

Natural Resources Canada

in conducting tests of the critical pathways, the model demonstrated that generally less than 50% of the variability in the dose to man could be accounted for by any single pathway. Given that this is a particularly useful index, it would be helpful if the contribution to variability for all pathways was determined by the BIOTRAC model. [Comment 715, Source Document ph2gov001, Page bio2]

an analysis of the sensitivity of particle travel times to hydraulic properties ... investigated the effects of a damaged and permeable WED combined with a permeable EDZ.... the high-permeability EDZ is connected to a major fracture via a single pathway through a permeable, damaged WED.... the sensitivity study presented here is incomplete and potentially misleading. Consideration should be given to the possibility of more than one high-permeability connection between the EDZ and fracture zones. [Comment 813, Source Document ph2gov001a, Page 14, Section 2.4.1]

Northwatch

the EIS does not provide a supported rationale for AECL's selection of sensitivity analysis parameters; consequently, the soundness of their selection cannot be assessed [Comment 1380, Source Document pub046, Page 15, Section d]

Scientific Review Group

The interaction between regional and local flow systems under various boundary conditions, and the effect of these interactions on contaminant travel time through the geosphere, should have been investigated. [Comment 390, Source Document tec004, Page 058, Section 6.3.2]

There is no sensitivity analysis with respect to the boundary conditions or other hydrogeologic parameters. [Comment 182, Source Document tec004, Page 187, Section E-3.1]

It is surprising not to see a special sensitivity analysis bearing on limiting factors and parameters affecting the critical group during their lifetime, but also generation after generation due to their cultural and dietary habits. For example, an upper limit to cultural and dietary habit of the critical group could be tested. [Comment 183, Source Document tec004, Page 187, Section E-3.1]

The vault scenario analyses include only restricted variations of critical parameters... the magnitudes of two critical parameters; eg. the thickness of the buffer layer and the backfill layer are not varied ... What is offered as a sensitivity analysis is really a perturbation of some of the controlling parameters within the single scenario.... In view of the high rock stress condition at the URL, the risk of development of a large-scale fracture that breaches the exclusion zone, should have been analyzed.... The groundwater velocity is varied over only two orders of magnitude (R-Vault 1994: p.236). This is a very small range as far as groundwater velocities go, and it makes sense only within the narrow confines of the reference site (see Appendix G in this report). The sensitivity analysis should have included a realistic range of groundwater velocities representing different locations of the repository within a regional flow system. [Comment 221, Source Document tec004, Page 203, Section F-2.1.5]

ecosystems and hydrological systems have changed significantly within the past 10,000 years and no argument is given for assuming that they will not continue to change during the future 10,000 year period of concern for the concept. It would appear to be important that a range of different possible scenarios or assumptions be explored through BIOTRAC, most importantly to determine how sensitive the model is to changes in input and conditions (R-Biosphere 1993: p.314). [Comment 277, Source Document tec004, Page 234, Section H-2.3]

OPG RESPONSE

These comments reflect a range of concerns. In some cases, they could have been addressed in the EIS by a better explanation of the reported sensitivities, in one case the comment was addressed by the addition of the Second Case Study, and in other cases additional studies would be required.

Overall, we have concluded that a future safety assessment will need to include an explicit treatment of a number of "what if" scenarios that test the robustness of the concept to various assumptions. Ideally, there will be an opportunity for defining these scenarios with the stakeholders (e.g. regulators, local community) during the safety assessment process, rather than waiting for the final report to see if the results of interest are included. One specific case that will certainly be more carefully treated in future is the effect of different geosphere conceptual models and/or hydrogeological boundary conditions.

7.03.13.03 Safety Assessment - Postclosure - Analysis of Results - Barrier Effectiveness

PARTICIPANT COMMENTS

Atomic Energy Control Board

In the evaluation of the effectiveness of each barrier (Postclosure PRD, p. 180) no explicit accounting is made for the retention time within the barrier. Since the predicted dose consequences are related to the contaminant release rate rather than to the cumulative mass released, using the total (integrated over time) discharged mass divided by the unit mass entering (Postclosure PRD, p. 522) does not seem to be an adequate measure of barrier effectiveness. [Comment 588, Source Document gov002, Page 35, Section B.3.4(i)]

The estimated effectiveness of the barriers is inconsistent with the assumptions of the modelling. One would expect that the first barriers (container, buffer, backfill) would be more effective at reducing releases of short-lived, highly-retarded radionuclides ... However, this is not what is shown in Figure 6-13 (Postclosure PRD, p. 184).... for 129I ... No explanation is offered why the curve estimated for the waste form effectiveness never approaches the assumed 8.1% IRF (Postclosure PRD, Figure 6-12).... since the container is assumed to disappear upon perforation, ... its performance measure should be unity. However, Figure 6-12 (Postclosure PRD, p. 181) shows it to be less than unity for 129I at early times. [Comment 589, Source Document gov002, Page 35, Section B.3.4(ii)]

Evaluation of the net effectiveness of the barriers is inaccurate. The barriers are not independent of each other, as stated in Section 6.4 (Postclosure PRD, p. 182). The discharge boundary condition for each barrier is controlled by the transport properties of the subsequent barrier, so the effectiveness of any barrier is determined by the rate of contaminant removal by the subsequent barrier(s).... It is not true that multiplying the fraction released by each barrier (as is done in Table 6-5) "greatly overestimates the actual release from a sequential combination of barriers" (Postclosure PRD, p. 182). It appears that the evaluation of barrier effectiveness is flawed, and Table 6-5 and Figures 6-13 and 6-14 in the Postclosure PRD misrepresent the real performance of the barriers. [Comment 590, Source Document gov002, Page 36, Section B.3.4(iii)]

Northumberland Environmental Protection (Fairlie)

the EIS should clearly show in tabular form the percentage of each main nuclide which is retarded by each barrier (fuel, titanium container, buffer and backfill, and the host rock) and by all barriers combined. [Comment 1341, Source Document ph2tec006, Page 03]

Northwatch (Lloyd)

Deficiencies Which Emerged or Remain Outstanding After Discussion in the Phase II Tehncial Hearing Sessions ...

- barrier effectiveness for radionuclide capture. [Comment 1536, Source Document ph2tec045, Page 22]

OPG RESPONSE

We agree that a better way of presenting information on barrier effectiveness is desired. However, there is no single correct approach to doing so. The reviewers have noted some general problems with the method used in the EIS (a different method was used in the SCS). We will observe what is used in other national studies, and likely try out some different approaches as part of future internal safety assessment exercises.

One possibility is to separate out the treatment of barrier effectiveness and barrier redundancy. The former might be tested by including just one barrier at a time (i.e. all other barriers artificially removed). The latter would be tested by removing one barrier at a time. These two approaches have

been used, for example, in the EPRI analysis of the Yucca Mountain repository (Kessler, 2002).

References

Kessler, J. 2002. Integrated Yucca Mountain safety case and supporting analysis, EPRI's Phase 7 Performance Assessment. EPRI Technical Report 1003334.

7.03.13.04 Safety Assessment - Postclosure - Analysis of Results - Threshold Exceedence

PARTICIPANT COMMENTS

Natural Resources Canada

The authors advocate the use of arithmetic averages of annual dose estimates (ADEs) from multiple SYVAC simulation runs to characterize the impact of alternative scenarios. This is an acceptable but underutilization of the Monte-Carlo method. They should also explain that Monte-Carlo simulation allows them to estimate the probability that the ADEs will exceed a certain threshold value such as that specified in the AECB guidelines. Concentration or dose threshold exceedance probabilities are a common way of characterizing environmental impacts and should at least be mentioned even if, subsequently, these probabilities appear to be zero for the present reference disposal system. [Comment 772, Source Document ph2gov001, Page pos2]

while it is acceptable to consider "average dose rate estimates" (i.e. dose rates averaged over numerous simulation outcomes) as required by AECB risk guidelines, the proponent must also present threshold exceedance probabilities calculated from the same simulation outcomes.... "average dose rate" calculated from many simulation outcomes is an incomplete and misleading criterion for measuring against regulatory limits when there exists a probability that, in some simulation outcomes, these limits are exceeded.... Figure 17, on page 56, (see also Figure 11, page 29 of volume 1) shows the percentiles of simulation dose rates against time.... there is a finite probability of exceeding the AECB dose rate limit within the regulatory 10000 a time frame. This is confirmed in Table 6 on page 55. [Comment 825, Source Document ph2gov015, Page 07]

OPG RESPONSE

The EIS approach with arithmetic average was based on the AECB R-104 regulatory requirement.

Nonetheless, it is acknowledged that the additional method of presenting results as suggested here has merit, if there are enough probabilistic runs and PDF data to support the estimates of what are likely "low probability" results.

However, the overall tone of the EIS/SCS panel review was that there was too much emphasis on probabilistic results, and therefore it is expected that probabilistic analysis will play a smaller role in a future safety case. For example, there will likely be more separate, deterministic "what if" calculations, for which probabilities may not be well defined. The value of presenting results as "fraction above threshold" will have to be re-evaluated in the overall context of the next safety case.

7.03.14 Safety Assessment - Postclosure - Presentation of Results PARTICIPANT COMMENTS

Atomic Energy Control Board

The discussion of the relative change in inventory due to decay (Postclosure PRD, p. 250) is insufficient without also including the initial inventory of the contaminants.... statements that the inventories of ... radionuclides will decrease by a factor of more than 1,000,000 seem inadequate justification for conclusions that they will result in negligible impacts. [Comment 586, Source Document gov002, Page 34, Section B.3.2]

Canadian Coalition for Ecology, Ethics and Religion

AECL's use of background radiation level as though it were a standard in several figures and in related discussion ... is confusing and misleading. [Comment 1873, Source Document ph3pub160, Page 8]

Canadian Voice of Women for Peace

we find the absence of justifications of ... the use of background radiation as an acceptability standard. [Comment 1912, Source Document pub003, Page 01]

Natural Resources Canada

The authors should ... discuss the fact that, in figure 6-9 a), small values of the WED lead to ADEs that are very close to the AECB guidelines. [Comment 778, Source Document ph2gov001, Page pos4]

In paragraph 2, the authors note that: "Under conditions of maximum vault heating effects and the lowest values of the range of rock porosity, the shortest advective travel time from the vault to ground surface was about 70 years." They offer no comment as to the significance of this finding. Is this a worse case scenario? If so, what are the implications?... Furthermore, is porosity the key factor here? Surely permeability would exert a greater control? In paragraph 4, no comment is made about the size of the area over which fluids would emerge at the surface. Is it acceptably small for a worst case scenario, or is it not? In short, what do the results of modelling imply? [Comment 832, Source Document ph2gov015, Page 18]

OPG RESPONSE

Presentation of the results of a future safety assessment in order to meet the needs of all readers will require some iteration. We will incorporate lessons-learned from the EIS and SCS reports, and from other international safety assessments. We are planning to use more "what-if" scenarios in future assessments so will need to be clear about context and implications.
7.03.15 Safety Assessment - Postclosure - Human Intrusion PARTICIPANT COMMENTS

Atomic Energy Control Board

The evaluation of the intrusion scenarios uses unjustified and overly optimistic probabilities of occurrence, resulting in an under-prediction of the risk. The overall risk of inadvertent human intrusion examines only the possibility of a borehole intersecting a waste container (Postclosure PRD, p. 244 and p. 246).... Since the minimum plan area of the contaminant plume will be about four square kilometres once a sizable portion of the containers fail, the conservative probability of intersecting contaminated material would be unity.... The repository would be visible to several different exploration remote sensing techniques as an anomaly. Since exploration drilling is not random but is directed to locate and delineate anomalies, drilling into the pluton containing the repository would be more likely than drilling into other plutons. Furthermore, if there is one borehole drilled then there would be a suite of boreholes drilled. Hence, the probability of multiple intrusions into the contaminant plume (Postclosure PRD, p. 245) would simply be equal to the probability that the site is targeted for exploration drilling. The probability of failure of active institutional controls (Postclosure PRD, p. 244) will likely reach unity much sooner than 500 years, since the controls under discussion include "security and surveillance measures" ... Similarly, the probability of failure of passive institutional controls (Postclosure PRD, p. 244) will likely reach unity much sooner than 2000 years [Comment 576, Source Document gov002, Page 27, Section B.1.3]

Canadian Coalition for Nuclear Responsibility (Regroupement pour la surveillance du nucléaire)

Containers may last for a long time without safeguarding their contents. The Egyptian pyramids are still there, very impressive long-lived containers, but their contents are gone. [Comment 1909, Source Document cs031, Page 03]

Environment Canada

studies by the Environmental Advisory Team have shown that mistakes (i.e. overestimating by 1000) have been made ... in relation to the impact of human intrusion. [Comment 859, Source Document gov003, Page 20, Section 2.9]

The inadvertent human intrusion scenario, which has a probability of occurrence of about 2% over 10,000 years, creates an open "borehole" from the vault to the surface. The intrusion scenario requires further study, including a probabilistic analysis, and consideration of an open-borehole scenario. [Comment 881, Source Document gov003, Page 30, Section 2.14]

Health Canada

Since [the human intrusion] scenarios dominate the total radiological risk associated with the concept, some estimate of uncertainty should be supplied. [Comment 957, Source Document gov006, Page 16]

Human intrusion scenarios, together with probabilities and uncertainties, need to be considered in greater detail. [Comment 970, Source Document gov006, Page 18]

there is no discussion of the impact of vault design on the estimates of risk and consequence for the intrusion scenarios.... Various designs have the potential of increasing or decreasing either the risk or the hazard associated with inadvertent intrusion. [Comment 992, Source Document ph2gov011, Page 08]

no estimate of uncertainty is given for the human intrusion scenarios. This is a major shortcoming since these scenarios dominate the total radiological risk associated with the concept. [Comment 993, Source Document ph2gov011, Page 08]

the proponent has also failed to analyze the long-term impact on vault integrity and radionuclide movement as a result of [inadvertent human] intrusion. [Comment 1028, Source Document ph2gov011, Page 08]

Northwatch (Lloyd)

Deficiencies Which Emerged or Remain Outstanding After Discussion in the Phase II Tehncial Hearing Sessions

- human intrusion (particularily intentional for criminal purposes or unintentional) [Comment 1540, Source Document ph2tec045, Page 22]

Scientific Review Group

The AECL considers two inadvertent human intrusions to be statistically independent (R-Postclosure 1994: p.242) and hence concludes that their joint probability must be extremely low. Why is this so? The probability may increase if the events are statistically dependent. [Comment 158, Source Document tec004, Page 171, Section E-2.1.4]

OPG RESPONSE

With respect to the EIS, the following specific points are made relative to the comments:

- Risks from the human intrusion scenario presented in the EIS (Goodwin et al. 1994) were incorrect (they were too low). The correct risks are given in Wuschke (1996). The new calculations showed that risks were largest for the resident scenario and reached about 1.0E-9 at 10,000 years and 2E-7 at 100,000 years.

- The revised calculations show that maximum risks for the human intrusion scenarios occur much later than 2000 years after closure (Wuschke 1996). Thus, the maximum risk is not affected if it is assumed that active and passive institutional controls disappear at say 100 years rather than 500 years and 2000 years, respectively.

- Only inadvertent human intrusion scenarios are investigated in the EIS. Scenarios for deliberate intrusion were excluded because it is reasonable to assume that a society wishing to retrieve materials from the vault would likely be aware of and capable of dealing with the hazards involved. Intentional sabotage was considered in the preclosure assessment document (Grondin et al. 1994).

- The human intrusion scenario only describes those cases where a surface borehole intersects the vault itself. Intersection of the contaminant plume is already covered in the groundwater or "SYVAC" scenarios (Goodwin et al. 1994b, p.242) in which a well is used as a drinking water source. In addition, the open-borehole scenario is investigated separately in Section 6.7.4 (Goodwin et al. 1994b). This scenario would likely also describe the long-term impact on vault integrity and radionuclide movement as a result of human intrusion.

- The probability of the human intrusion scenario was based on the area of the vault and the number of boreholes drilled (per unit area). In this calculation the estimates of future drilling rates were inflated by about two orders of magnitude over historical rates of drilling in the Canadian Shield. Thus, the assigned probabilities are not overly optimistic. It is true that if the repository stands out in any way (due to anomalies) then the probability of intrusion would be greater. However, Lodha and Tomsons (Appendix C of Wuschke 1996) modelled the magnetic and gravity anomalies that would be created by the vault specified in the case study and concluded that the vault would not be detectable by gravity of magnetic surveys.

- There is no physical means by which the contents of a container can escape from the container, if the container does not fail. In the EIS, for conservatism, it is assumed that if the container fails, then the container no longer hinders the transport of contaminants out of the container, regardless of the

size of the defect in the container. In contrast, in the SCS, a container continues hinders the release of contaminants from the container. The mass transport resistance of the defect can be very important in reducing the calculated doses.

More generally, the EIS indicated that the human intrusion scenario was important to consider in safety assessments. Of course, one rationale for the deep geologic repository concept is to minimize this risk by locating the repository deep underground and in areas with little economic value. Recent international guidelines for solid radioactive waste disposal (ICRP 81) have indicated that human intrusion should be explicitly considered but separately from natural evolution scenarios, and provided some guidelines. It is likely that this pathway will need to be considered by stylized exposure scenarios such as those described by Wuschke (1996) for the EIS, although there is as yet no international consensus on what those scenarios should be. Recent work for the OPG Third Case Study largely followed the Wuschke (1996) approach, but explicitly separated the dose consequences from the risk. Future treatment of this topic in OPG assessments can be traced first through the corresponding OPG FEPs Database entries under #1.4 Future Human Actions (e.g. Gierszewski et al. 2003. Third Case Study - Features, events and processes. OPG report 06819-REP-01200-10125).

References

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Wuschke, D.M. 1996. Assessment of the long-term risks of inadvertent human intrusion into a proposed Canadian nuclear fuel waste disposal vault in deep plutonic rock - Revision 1. Atomic Energy of Canada Limited Report AECL-10279 (Rev. 1).

8 DOCUMENTATION

PARTICIPANT COMMENTS

Atomic Energy Control Board

Documents cited in the EIS and PRDs as providing support for an AECL statement or additional information often do not contain the expected information. [Comment 567, Source Document gov002, Page 22, Section A.6.2]

The EIS and its supporting documentation do not provide sufficient information of the URL site and the WRA to allow reviewers to conduct independent analyses.... the types and quantities of data required to develop conceptual models are generally not publicly available.... there is no compilation of the available permeability data for the site, with the data categorized by test or rock type, or reliability of the data. Furthermore, AECL has published virtually no analyses showing the trends and spatial variations in the data as a function of rock type, depth and scale of measurement.... If the concept is implemented, the implementing agency should make all site data publicly available, and the data should be compiled into databases to make it more accessible. [Comment 569, Source Document gov002, Page 22, Section A.6.3]

The documentation of the development of SYVAC3 and the CC3 simulation package is still incomplete. Much of the software specification was not documented when the EIS was published in 1994. [Comment 583, Source Document gov002, Page 32, Section B.2.4]

AECL has not provided a detailed review of the available geologic and hydrogeologic data for the WRA/URL area or justified the structure and parameterization of their groundwater flow models based on that data in the EIS, the PRDs, or any of the tertiary references.... Also, additional information is required on the configuration of the finite element grid, and in particular around the vault, to assess how features such as the excavation damage zone and waste exclusion zone were physically modelled, and where the particles that were used in the groundwater travel time calculations were released. This information is required to assess the appropriateness of the conclusions made based on the modelling results. [Comment 629, Source Document gov002, Page 55, Section C.2.7]

Campaign for Nuclear Phaseout

include a checklist of parameters and categories of data used in EIS models. [Comment 1812, Source Document pub027, Page 28, Section III.F]

Canadian Coalition for Nuclear Responsibility (Regroupement pour la surveillance du nucléaire)

give a thorough discussion of ... mathematical modelling ...

- a clear explanation of the scientific method ...

- a clear explanation of the hypothetical nature of a mathematical model, and the consequent need to try to validate or invalidate a model ...

- simple examples of "good" (valid) and "bad" (invalid) mathematical models ...

- a discussion, with examples, of models that give incorrect results because of (1) incorrect data; (2) "bugs" in the code; (3) conceptual errors in the model;

- an explanation of the vastly different behaviour that can be experienced by iterating linear models as opposed to non-linear models, with a brief explanation of so-called "chaotic behaviour";

- an explanation of the special difficulties posed by modelling discontinuous processes ...

- an explanation of the dangers inherent in extrapolating a model's results beyond the range of parameter values within which the model has been experimentally validated;

- an explanation of the fundamental difficulty of knowing whether or not a computer code has been fully de-bugged ...

- an explanation of the differences in predictive ability of mathematical models in (a) the physical sciences; (b) the biological sciences; (c) the social sciences. [Comment 1889, Source Document pub049, Page 31]

For each submodel, ... list all of the input parameters in a table, with a brief explanation of what each one means. In the table, the probability distribution or range of values for each parameter should be specified, with an indication of how it was arrived at ... Similar questions apply to the SHAPE of the probability distribution (in other words, where the "most probable" values are assumed to be) [Comment 1891, Source Document pub049, Page 33]

All mathematical & scientific assumptions that have been made about processes and mechanisms in constructing various mathematical models should be laid out, preferably in an organized tabular format. There should also be an accompanying explanatory text to discuss the justification for & possible significance of those assumptions. In particular, the proponent should identify all examples of, and discuss in an organized and comprehensive way, each of the following: the use of linear models to model non-linear behaviour; the way in which discontinuities are incorporated (or not) into the models; the way in which couplings are incorporated (or not) into the models; the use of probabilistic assumptions in dealing with parameters and processes which may not be random; overriding assumptions [Comment 1892, Source Document pub049, Page 35]

Chemical Institute of Canada

In Section 7.8(pp.296-299[10711]) mean dose rate versus time estimates are provided without any clear indication how Figs. 7.7 (p.297) and Fig. 7.9 (p.299) were obtained. [Comment 1120, Source Document tec005, Page 13, Section II.ii.C1]

In [10714] release rate versus time plots appear at several places, ... There are no related dosage plots given, with the notable exception of Fig. 7.1 (p.197). However, no explanation is provided how the data in Fig. 7.1 were obtained (presumably from release rate versus time data), and with respect to what spatial reference position (see C3). [Comment 1121, Source Document tec005, Page 13, Section II.ii.C2]

The estimation of dosage rates is obscure.... Since the dose rate is distance-dependent, Fig. 7.1 (p.197[10714]) should clearly indicate the vaule of R, or, whether the dose rate is given as a mean value over a certain clearly defined distance from the radiation source. [Comment 1122, Source Document tec005, Page 13, Section II.ii.C3]

An alternative estimation scheme, carried out on the basis of interaction of beta particles with matter (Chapter 5, Turner), and radiation dosimetry (Chapter 10, Turner) also leads to puzzling results.... There is no indication in the quoted AECL reports whether this or a similar estimation had been used, or if there is an entirely different computation path to be followed. [Comment 1123, Source Document tec005, Page 14, Section II.ii.C3]

Ecosystem Approach Group

The EIS summary ... is accompanied by several misleading tables ... it is accompanied by color pictures that convey a pseudo technological terrorist message or only put forward the best face [Comment 2038, Source Document pub033, Page 10]

Joint Committee of the Canadian Academy of Engineering and the Royal Society of Canada

Details are requested on the range (and standard deviation) of the parameters used in the SYVAC simulations or parallel assessments of hazards posed by nuclear fuel waste. These should include data on the natural variations in background radiation as well as the hazards due to the chemical toxicity of the longer-lived isotopes produced in nuclear fuel waste or its containers. [Comment 1138, Source Document tec003, Page sgw2]

McMaster Institute for Energy Studies

A description of the term habitat, its ecological significance as well as the implications of impact to habitats should have been outlined. Ecological phrases such as "early successional communities" (describing plant/animal species which colonize a region after a disturbance) should also have been explained. [Comment 1438, Source Document phpub033, Page 16]

Mouvement Vert - Mauricie

AECL often uses approximative language, substituting qualitative opinions for measurable, quantifiable values.... The MVM would like AECL to quantify and document all statements of a scientific nature contained in the text ... All references would have to include not only the name of the work being cited, but also the exact page on which the information can be found. [Comment 1477, Source Document pub024, Page 10, Section 2.1.3]

National Action Committee on the Status of Women

In addition, any future documentation issued by the proponent or other bodies should be translated into Aboriginal languages in order to ensure access to the information by those who will most likely be directly impacted. [Comment 1315, Source Document pub026, Page 63, Section 7.13]

Natural Resources Canada

it was reported that 61% of northern Ontario is underlain by sand (p. 147). This percentage is too high. This proportion may well be made up of sand and sandy till, however the sandy till should likely be regarded as sandy loam rather than sand with respect to variables such as permeability. [Comment 721, Source Document ph2gov001, Page bio5]

evaluation of the theoretical predictions of breakout yielding is not feasible from the information provided. [Comment 763, Source Document ph2gov001, Page eng1]

The fracture zones in the Lac du Bonnet batholith are described as cooling cracks, of Archean age, although evidence by which the dates of the fractures are determined is not presented.... without evidence to the contrary, it is unlikely that all the fractures are more than 2300 million years old. [Comment 729, Source Document ph2gov001, Page geo1]

Northwatch

The EIS repeatedly used technical words which are unfamiliar to the public and were not included in the glossary, [Comment 1350, Source Document pub046, Page 03, Section c.1]

The EIS repeatedly and frequently made conclusive statements which were unsupported in their presentation, and were without references or a scientific basis [Comment 1351, Source Document pub046, Page 03, Section c.1]

The EIS repeatedly makes incomplete references to other documents, generally not including the page or section identification, making reference impracticable; the references should be specific, and allow the reviewer to locate the reference, [Comment 1353, Source Document pub046, Page 04, Section c.1]

The EIS contains frequent and numerous references to reports which are not included in the bibliography [Comment 1354, Source Document pub046, Page 04, Section c.1]

The EIS did not include an index, making location of items and follow through on subject areas extremely difficult; the EIS should include a complete master index [Comment 1355, Source Document pub046, Page 04, Section c.1]

the EIS should clearly state the assumptions which the proponents have made, and the basis for acceptance of those assumptions [Comment 1373, Source Document pub046, Page 15, Section d]

OECD/NEA Review Group

The backfill would be a significantly less effective barrier if the flowing zone were located underneath the vault. This fact did not escape the AECL researchers, but it is not described sufficiently in the EIS. [Comment 1207, Source Document tec001, Page 09, Section 3.1.4]

The Group considered the extrapolation of the very positive results from the reference case to other cases in the concept to be plausible, but certainly not adequately justified by the information available in the report. [Comment 1233, Source Document tec001, Page 14, Section 4.3]

Analysis of the results points out that large portions of dominant radionuclides remain in the waste form and container over time periods longer than 100,000 years. While this is meant to underline the enormous retention potential in the Reference Case, the presentation to the public should at the same time emphasize what happens to this remaining inventory - and almost unchanged hazard potential - over very long time periods. [Comment 1235, Source Document tec001, Page 14, Section 4.3]

The supporting Primary References, ... could benefit from:

- A 'vertical slice' of the post-closure safety assessment volume, guiding the reader explicitly through the key performance issues and sensitivities and how they were handled. This might be a separate summary report.

- ... presentation of more of the key quantitative information on which the models or assumptions are based.

- The EIS is a weighted selection of other reports and is considered appropriate for the intended purpose. A similar report, weighted towards post-closure safety, could be useful [Comment 1255, Source Document tec001, Page 19, Section 6.1]

Ontario Association for Environmental Ethics

Whenever the relative frequency/probability of a single event is asserted, the spatial and temporal boundaries must always be specified so that the reference class is clearly identified. Furthermore, the numerator in any expression of the relative frequency of a single event must always be 1. [Comment 1626, Source Document phpub088, Page 12]

Rare events should be expressed in whole numbers (e.g. 8 events per 1,000,000 years) to provide a clear framework for their analysis rather than as probability assertions expressed relative to a comparatively small time period (e.g. 0.000008/yr). [Comment 1631, Source Document phpub088, Page 28]

Saskatchewan Environmental Society

AECL ... never provides the reader with page references. [Comment 1663, Source Document pub040, Page 01, Section 02]

Scientific Review Group

The structure of the AECL Environmental Impact Statement (EIS 1994), which separates processes in the vault (R-Vault 1994), the geosphere (R-Geosphere 1994), the near-surface and surface environment (R-Biosphere 1994) and postclosure issues (R-Postclosure 1994) makes it difficult to consider the effect of the repository on the biosphere as a whole, or to assess the essentially integrated role that biological processes may play in enhancing and restricting transfer of radionuclides from the fuel waste to humans. [Comment 401, Source Document tec004, Page 065, Section 6.4.2]

The primary reference documents do not systematically discuss the data obtained from ... boreholes, or even give the locations of the boreholes. [Comment 8, Source Document tec004, Page 107, Section A-2.1.4]

AECL has explained the risk analysis plan in Chapter 2: The Performance Assessment Approach.... The approach uses different terminology and a different organization than is currently common practice [Comment 144, Source Document tec004, Page 167, Section E-2.1.2]

Although parts of the assessment method are well explained and clearly illustrated (e.g. the pathway diagrams for the biosphere), the overall structure and function of the assessment models is difficult to grasp; therefore, transparency is lacking. [Comment 145, Source Document tec004, Page 168, Section E-2.1.3]

There is no discussion of the detailed methods used to calculate the annual dose equivalent. [Comment 186, Source Document tec004, Page 188, Section E-3.2]

The geoscience data required for the documentation of the models that are presented in this document have been omitted from the document. This involves both regional and local geoscience data... This lack of documentation is most glaring when it comes to critical parameters such as permeability and effective porosity, especially those of the sparsely fractured rock which is said to surround the vault ... During visits to the WRA and the URL the SRG was made aware of a significant body of important unpublished information concerning the suitability of part of the Lac du Bonnet granite as a host rock for nuclear fuel waste repository. That information has not been presented in R-Geosphere.... Among all the k data in the table, only those corresponding to layer 1 (the upper 150 m) are supported by even a brief description of field observations ... no similar information, and no actual data, are provided for any other k-values in Table ES.1 (R-Geosphere 1994: p.vi). [Comment 234, Source Document tec004, Page 214, Section G-3.1.2]

U-series disequilibrium studies on granites and fracture zones, which would provide a constraint on the mobility/ immobility of U and daughter products over time scales of 100,000 - 1,000,000 years, have not been documented in Appendix A.3 (R-Geosphere 1994: pp.326-328) of this document. [Comment 245, Source Document tec004, Page 219, Section G-3.2.6]

OPG RESPONSE

These comments relate to the presentation of information in AECL's EIS and primary references, and are not specifically technical comments. However, there are a number of points which may be noted for future inclusion in a site-specific assessment:

- Cross-references to supporting information should be valid;
- Provide site geological and hydrogeological information;
- Document the software;
- Provide a list of model data and values used;
- Discuss modelling considerations and potential software problems;
- List key assumptions;
- Provide intermediate results for key calculations to allow the reader to follow the calculations;
- Define all terms;
- Provide page numbers for references;
- Translate material into aboriginal languages;
- Use current definitions for risk terminology;
- Provide an index;
- Provide a summary of the safety assessment and key performance issues;
- Provide an integrated description of what happens

Some specific suggestions are already being addressed, e.g. through development of software documentation, and an integrated desciption of the expected evolution of the system. Many of the other points are simply good practice for writing technical documents of the scale of the EIS. We anticipate a somewhat different organization of the primary and reference documents in any future assessment, which should help make them more traceable and reviewable.

9 OPTIONS

9.01 Options - Requirements

9.01.01 Options - Requirements - Risk Comparison

PARTICIPANT COMMENTS

Campaign for Nuclear Phaseout

The AECL EIS fails to present worst case scenarios with regard to the security of stored high level waste.... The EIS ... should be organized in a manner that readily allows for a comparison of worst case scenarios for both above ground and below ground storage. [Comment 1782, Source Document pub027, Page 17, Section III.B]

Canadian Coalition for Ecology, Ethics and Religion

Looking only ten thousand years into the future, supporters of deep burial see little danger to future generations, ignoring the later problem, which is the enormous increase in radiation releases predicted for the longer term.... would any other course of action expose them to doses that can be shown to be substantially lower over such a long time period? And how do the dose distributions over human populations, species, geographic area and time compare? [Comment 1840, Source Document phpub043, Page 34, Section 13]

Canadian Coalition for Nuclear Responsibility (Regroupement pour la surveillance du nucléaire)

justify the need for a permanent disposal option, by specifying the possible harmful consequences to human health and the natural environment that might follow from a postulated failure of current containment methods [Comment 1879, Source Document pub049, Page 15]

Concerned Citizens of Renfrew County

Insist upon a principle of minimum human exposure (including workers and the general public) to set radioactive waste management priorities and choose among alternatives [Comment 1970, Source Document phpub171, Page 2]

Neither the HLW nor the LLW studies compares waste management alternatives from the perspective of minimizing total population dose. [Comment 1972, Source Document phpub171, Page 2]

the HLW EIS ... fails to examine the potential of long-term storage to minimize radiation doses received by workers and the general public during waste handling and transport. [Comment 1973, Source Document phpub171, Page 3]

Earth Resources Society of Elliot Lake (Krauss and Dube)

Is there more danger for radiation exposure to occur from primary storage than there is from a disposal vault? [Comment 2014, Source Document pub002, Page 07, Section 5]

Energy Probe (Rubin)

ensure that no irreversible steps are taken until we are confident that we can quantify [total population, individual, and environmental] risks, and confident that we have done all that is humanly possible to minimize them. [Comment 2066, Source Document phpub041, Page 05]

two sections of the ACNS report ... recommend "ALARA-type" procedures to compare alternatives on the basis of their predicted collective risk commitment, as well as their costs.... AECL has provided none of the information that would be essential to carry out these comparisons: (1) a range of alternatives to be, compared, (2) the predicted collective risk commitment" (what we have called "total population radiation dose") of each alternative, and (3) the approximate costs, and social impacts, of each alternative. [Comment 2074, Source Document phpub041, Page 14]

The Panel must expressly insist - and must demand that the regulatory regime insist - that any proponent or implementer of nuclear waste disposal must assess the total predicted impacts of its proposal, for both average and more extreme scenarios, and must demonstrate that those total impacts are less than those of alternatives that are available or likely to become available in the next several decades. [Comment 2075, Source Document phpub041, Page 15]

Health Canada

Nor does the EIS main document contain a comparison of risks between an extension of the current fuel waste management practices, and those that would be incurred as a result of concept implementation. [Comment 2154, Source Document gov006, Page 07]

it would be desirable to put the potential risks associated with the concept in the context of potential risks associated with alternatives. Alternatives were described in the EIS but a detailed comparison was not provided. [Comment 1005, Source Document ph2gov011, Page 14]

Inter-Church Uranium Committee (Fortugno)

Why are alternatives to the concept not examined in relation to the relative risks to both host and affected communities? [Comment 2105, Source Document ph2pub031, Page 6, Section IV]

Mouvement Vert - Mauricie

AECL does not explain why medium-term accumulation of waste in interim storage modules at the power plant sites is unacceptable. The risks posed by interim storage over 100 to 150 years have not been demonstrated. [Comment 1478, Source Document pub024, Page 13, Section 2.2.1]

the project does not considerably reduce the consequences of a serious accident or failure in the interim storage system, which will continue to contain the recent spent fuel and will necessarily require major institutional controls. [Comment 1479, Source Document pub024, Page 13, Section 2.2.1]

National Action Committee on the Status of Women

AECL's proposal only considers one waste disposal option, and fails to compare it with long term onsite storage. [Comment 1278, Source Document pub026, Page 14, Section 4.1]

NAC opposes the use of risk assessment methodology as currently applied to make decisions which are as profoundly political as the decision whether or not to accept the proposed concept. It is our position that the use of risk assessment does not permit us to truly and accurately evaluate the potential consequences of concept implementation, ... The choice of which models to use, which variables to insert, which possibilities to consider, and which outcomes to discount or downplay rests with the risk assessment "experts". The outcome of this process is that decisions about what level of risk is acceptable to society, who will bear what level of risk, and which risks we should be most concerned about, decisions which are fundamentally political and social in nature, are removed from the social and political realm, and made by scientists and "experts" who have no accountability to the public. [Comment 1308, Source Document pub026, Page 47, Section 7.7]

Northumberland Environmental Protection

Since ionizing radiation can produce a lasting genetic load on future generations, this must be an upfront consideration in making decisions re nuclear waste disposal. Alternative disposal methods need to be assessed with this in mind. [Comment 1336, Source Document ph2pub020, Page 08]

Northwatch

a "worst case" scenario should be provided of each of the various alternatives or options, and a comparison done, including continuing current methods, long term above ground storage, long term below ground storage, and irretrievable "disposal", as proposed in the AECL "concept" [Comment 1362, Source Document pub046, Page 12, Section d]

Nuclear Awareness Project

Further options for long-term high level nuclear waste management (including monitored, retrievable storage; reduction at source; and transmutation) should be studied in a program managed by an independent agency, funded by nuclear power producers, and subjected to a full public review. This research should be detailed enough to permit a complete comparison with AECL's burial concept. [Comment 1619, Source Document cs018, Page 1]

There is still insufficient information on alternatives to burial in the Canadian Shield "to permit a meaningful comparison with the concept" [Comment 1614, Source Document ph3pub138, Page 2]

Quebec Public Interest Reseach Group at Concordia (QPIRG)

AECL's proposed concept for nuclear waste disposal is misleading in that only a portion of our nuclear waste will be stored underground at any given time. Because of the time needed for the waste to cool before it is buried, most of the waste will remain above ground at the point of production. This would mean that by adding the burying of nuclear waste to the processes of production and cooling we will not be alleviating the problem of waste accumulation, but rather creating new hazards. [Comment 1662, Source Document cs032, Page 2]

Saskatchewan Environmental Society

If indeed what we are going to need to consider is a proposal for a long term monitored retrievable storage system, we then need to have a much more thorough review of the various options for such a system. It may well be that something quite similar to what has been proposed would be the best choice, but there are certainly other options. The risks and benefits of these alternatives need to be evaluated. [Comment 1695, Source Document ph2tec039, Page 5]

some of the options for which conceptual work and site specific Environmental Impact Statements should be prepared include: (1) long term, monitored, retrievable storage above ground at a centralized location (2) long term, monitored retrievable storage below ground at a centralized location (3) long term, monitored storage deep underground. [Comment 1706, Source Document ph3pub006, Page 4]

Scientific Review Group

although future risks due to human behaviour cannot be controlled, a disposal system designed and sited in accordance with the generic concept, and constructed, filled and sealed using appropriate quality control procedures, may pose less of a hazard to future generations and the environment than fuel waste kept in storage or disposed of by other methods that have been considered to date. [Comment 328, Source Document tec004, Page 032, Section 5.1]

OPG RESPONSE

In 2002, OPG and the other nuclear energy corporations in Canada formed the Nuclear Waste Management Organisation (NWMO). The NWMO was established in accordance with the federal Nuclear Fuel Waste Act to investigate approaches for long-term management of Canada's used nuclear fuel. The NWMO must submit the study within 3 years (i.e., by November 2005) and the federal government will then decide on the preferred approach for long-term management of used nuclear fuel waste in Canada. These approaches include, but are not limited to, on-site storage at

reactor sites, centralised storage either above or below ground, and disposal on the Canadian Shield.

The NWMO will include an assessment of the risks and benefits associated with each approach.

9.01.02 Options - Requirements - Control

PARTICIPANT COMMENTS

Action Against Nuclear Waste Committee

AECL should abandon its plan to dispose of waste in the pre-Cambrian shield and maintain aboveground storage of these wastes until a method of detoxifying them is found. [Comment 1770, Source Document phpub030, Page 4]

Algoma Manitoulin Nuclear Awareness

It is trite to say that in the future we may have a use or a method of de-radioactivating the material only to know that it is unavailable. There are as well the dangers of entry into ground water that have been well documented throughout this hearing. It is therefore submitted that the application be denied at this time until it is proven that this irreversible course is the only one available. [Comment 1772, Source Document ph3pub133, Page 1]

Campaign for Nuclear Phaseout

The EIS fails to demonstrate how it would be possible to eliminate the need for continual monitoring of a facility, without incurring unacceptable risks. [Comment 1780, Source Document pub027, Page 14, Section III.A]

Canadian Coalition for Nuclear Responsibility (Regroupement pour la surveillance du nucléaire)

If we bury radioactive waste deep in underground rock and seal up the openings, then by the time anyone on the surface notices that the repository is leaking, it will be literally impossible to take effective corrective action. Even if the repository is re-opened and the waste removed, the extent of contamination underground would be so massive that little would be accomplished by such an operation. Irretrievability equals irresponsibility. Such an approach is unacceptable. [Comment 1900, Source Document ph3pub188, Page 1]

Catholic Women's League of Canada

We believe it is better to wait than to enter an irreversible path to a potential for catastrophe when there may be a better solution in a tomorrow. [Comment 1924, Source Document ph3pub009, Page 5]

Monitored, retrievable, above-ground storage of high-level nuclear waste is the least objectional option currently available to us. [Comment 1925, Source Document ph3pub009, Page 5]

Catholic Women's League of Canada - Manitoba

We believe it is better to wait than to enter an irreversible path to a potential for catastrophe when there may be a better solution in a tomorrow. [Comment 1927, Source Document ph3pub233, Page 1]

Continued monitored, retrievable, above-ground storage of high-level nuclear waste is the best of a 'least bad' option in our present history. [Comment 1928, Source Document ph3pub233, Page 1]

Catholic Women's League of Canada - Ontario

reject the concept of non-retrievable, non-monitored, deep disposal of nuclear waste. Monitored, retrievable, above ground storage is the least objectionable option currently available. [Comment 1933, Source Document ph3pub209, Page 4]

Concerned Citizens of Manitoba

leave the waste in above-ground, constantly monitored storage until such time as a decision is made to stop the production of this waste. After such a decision is made, the issue of extremely long-term management - not disposal - can be addressed. [Comment 1962, Source Document ph3pub050, Page 5]

One of the hallmarks of a safe management solution must be that it is reversible - ie if it is found in the future that what we in 1996 thought was safe is not safe, it must be reasonably easy to gain access to the waste and to institute another waste management plan. We do not believe that re-mining a shaft and vault in order to retrieve waste is a feasible option. [Comment 1960, Source Document phpub153, Page 8]

Conservation Council of New Brunswick

irretrievability equals irresponsibility. Such an approach is unacceptable. [Comment 1991, Source Document ph3pub162, Page 3]

Earth Resources Society of Elliot Lake (Krauss and Dube)

We should be able to get back to the used fuel and use it to our advantage if technology evolves to do so. [Comment 2018, Source Document pub002, Page 08, Section 5]

If you seal the vault up, you lose control. [Comment 2019, Source Document pub002, Page 08, Section 5]

Energy Probe (Rubin)

the object is consequence limitation, disaster avoidance, or prudence.... characteristics that are a threat to prudence are irreversibility and lack of effective monitoring. [Comment 2134, Source Document ph2tec024, Page 6]

This Panel needs to choose a reversible option that will minimize the chance of disaster - monitored retrievable storage for perhaps a century, while looking for better long-term options [Comment 2064, Source Document phpub041, Page 03]

We continue to believe that it is no favour to future generations to place extremely long-lived wastes irretrievably into a repository which will surely leak. Practical retrievability is an essential feature of an acceptable repository, at least until absolute safety, can be guaranteed. [Comment 2079, Source Document phpub041, Page 20]

Environment North

Fanatics who consider terrorism and blackmail as legitimate political strategies could attempt to steal Canadian nuclear waste to contaminate U.S. territory in acts of sabotage or vengeance. Security should be tight at present spent-fuel depots. [Comment 2087, Source Document ph3pub106, Page 1]

Should future technologies devise ways of neutralizing the waste, or of recovering and using the remaining energy or materials in the spent fuel, it cannot be easily and safely retrieved from deep rock, water-filled storage, encased in reinforced concrete. [Comment 2090, Source Document ph3pub106, Page 1]

Global Citizens Forum

In the handling and management of nuclear waste, there must be developed a community ethic and expertise that can be passed from one generation to the next, hence establishing the community's ability and authority to make decisions for the public good. [Comment 2096, Source Document ph3pub022, Page 1]

Groupe de recherche en interet public du quebec a l'Universite de Montreal

Ce concept est irréversible et compromet la sécurité et la viabilité de ce projet. [The concept is irreversible and compromises the safety and viability of the project.] [Comment 2097, Source Document ph3pub187, Page 2]

Groupe ecologiste de l'Universite de Moncton

Ne pas vouloir entretenir et monitorer la substance la plus toxique au monde est une absurdité totale. [To not want to maintain and monitor the most toxic substance on earth is a total absurdity.] [Comment 2099, Source Document ph3pub237, Page 1]

Halton Rape Crisis Centre

KEEPING NUCLER FUEL WASTE FULLY ACCESSIBLE FOR SAFE MANAGEMENT IS OUR ONLY INTELLIGENT OPTION. [Comment 2101, Source Document ph3pub144, Page 1]

Health Canada

It might be useful to design storage facilities with the capacity for easy future access, yet affording the security and human health and environmental protection components required. [Comment 1004, Source Document ph2gov011, Page 13]

International Institute of Concern for Public Health (Bertell)

Engineered retrievable waste, should I think, be the preferred model, especially in view of the poor radiation protection standards which we have today. Future generations should not be denied choice. [Comment 2123, Source Document ph3pub105, Page 1]

Joint Committee of the Canadian Academy of Engineering and the Royal Society of Canada

More secure, long-term used fuel management is clearly necessary and we conclude that the AECL disposal concept, in principle, can fulfill that need. We note that our conclusion is in harmony with similar judgements reached by other bodies, specifically the Scientific Review Group (SRG) and the Technical Advisory Committee (TAC), who also find the concept to be acceptably safe and effective. [Comment 1181, Source Document ph3tec001, Page 3]

Kenora Committee Against Nuclear Waste

We are opposed to the proposal to hide nuclear waste in the Canadian Shield. This of course means we are opposed to it being placed anywhere it cannot be monitored and shielded from all life forms. [Comment 2126, Source Document ph3pub063, Page 01]

l'Union Sain-Laurent Grands Lacs

En attendant une vrai solution, isoler les déchets nucléaires par un entreposage sécuritaire sous haute surveillance duquel les déchets pourront être facilement retirés.

[While awaiting a real solution, isolate the nuclear wastes in secure, monitored storage from which they can be easily retrieved.] [Comment 1463, Source Document ph3pub194, Page 2]

Le concept est irréversible ce qui est imprudent étant donné les problèmes potentiels liés à cet entreposage (fuite d'eau, création d'une zone de fracture etc...)

[The concept is irreversible, which is not prudent given the potential problems of such storage (groundwater flow, creation of fracture zones, etc.).] [Comment 1464, Source Document ph3pub194, Page 3]

Montreal Raging Grannies

Keep waste at the surface - and monitor well. And don't buy this burial scenario from hell! [Comment 1473, Source Document ph3pub186, Page 1]

National Action Committee on the Status of Women

the EIS does not consider the possibility of closely monitored, retrievable above ground storage, [Comment 1312, Source Document pub026, Page 61, Section 7.11]

National Council of Women of Canada

The multiple barriers proposed in the concept would appear to offer adequate protection to both humanity and the natural environment [Comment 1316, Source Document pub001, Page 1]

Northumberland Environmental Protection

proposal for geologic burial must be rejected, and a request made for alternate disposal options that can be monitored and readily retrieved. [Comment 1337, Source Document ph2pub020, Page 13]

If the decision in Port Hope this past year is any kind of benchmark, the people might rather consider storage that is monitorable and retrievable. [Comment 1325, Source Document phpub092, Page 02]

Project Peacemakers

We ask that the status quo prevail for at least the next fifteen years, until a much more appealing option for dealing with high-level waste is presented to the Canadian public for consideration.... waiting for some time to pass, waiting for a discovery, waiting for our best minds to think again and think longer, until thinking yields some better ideas [Comment 1654, Source Document ph3pub066, Page 2]

Provincial Council of Women of Ontario

Would it not be a better ethical decision to decide as Holland has, that there must be a facility for longterm storage of retrievable waste, with every opportunity for human intervention, in order to carry out control activities and that the wastes not only must be retrievable but the process reversible? [Comment 1655, Source Document ph3pub130, Page 2]

Quebec Public Interest Reseach Group at Concordia (QPIRG)

If radioactive waste is buried and sealed deep in underground rock, by the time anyone on the surface notices that the repository is leaking, it will be literally impossible to take effective corrective action. [Comment 1661, Source Document ph3pub189, Page 3]

Risk Assessment Society

final disposal of what is now regarded as waste, may be depriving future generations of a valuable resource. Thus, we submit that the storage, rather than disposal is an important public issue that extends to future generations. [Comment 1424, Source Document cs011, Page 2]

Robertson, J.A.L.

In the light of recent events in the former USSR, "a few hundred years" may be a gross overestimate for the longevity of institutions. Closer to home, banks and other institutions that appeared permanent have disappeared, almost overnight. This only stresses the AECB's preference for solutions that do not depend on institutional control. [Comment 1452, Source Document phpub004, Page 11]

Saskatchewan Environmental Society

Perpetual monitoring of the high level nuclear wastes must be possible.... It has become clear during these hearings that the technology is not yet available to provide the degree of security through very long term monitoring which would be required for public confidence. [Comment 1702, Source Document ph3pub006, Page 1]

One of the things which needs to be examined is how the proposed system would be predicted to behave if long-term vault monitoring were incorporated using present technology.... We need, for the time being, secure, long-term, monitored storage. It is conceivable that such a storage mechanism could eventually evolve into a permanent management system if and when appropriate technology emerges. [Comment 1708, Source Document ph3pub010, Page 2]

although the proposed concept for disposal is not a satisfactory solution, there is not a good alternative ready to be proposed.... we are going to have to choose a "least bad" option rather than a "good" one.... Much as we would like to avoid saddling our grandchildren and great grandchildren with the responsibility of supervising and guarding our wastes, at present the best we can hope to come up with is a monitored, retrievable storage system which will require on-going care by future generations. [Comment 1676, Source Document phpub032, Page 2]

Perpetual monitoring of the high level nuclear wastes must be possible. [Comment 1678, Source Document phpub094, Page 3]

the focus of Canada's siting discussions should shift to a siting process for interim, longer term, monitored, retrievable storage of Canada's high level nuclear waste. [Comment 1680, Source Document phpub094, Page 3]

Scientific Review Group

The need for an acceptable technology for disposal of nuclear fuel waste follows from two premises that are widely held in Canada and internationally:

- the burden imposed on future generations for the continued management of the wastes produced by the current generation should be minimized; and

- methods of ensuring the necessary institutional controls, such as security measures, monitoring and regular maintenance, upon which safe storage of nuclear fuel waste depends, are not considered to be reliable beyond a few hundred years.

The SRG agrees with these premises and with the need for an acceptable technology for nuclear fuel waste disposal. [Comment 320, Source Document tec004, Page 002, Section ES]

South Bruce Impact Advisory Committee

the proposed deep ground disposal concept [should] remain flexible to accommodate other options which may present themselves over time, due to advancing technologies [Comment 1725, Source Document ph3pub110, Page 5]

all disposal options developed [should] include an aggressive monitoring and maintenance program to monitor technical and environmental stability and safety [Comment 1726, Source Document ph3pub110, Page 5]

Temagami Lakes Association

this waste product should be considered a future resource for some as yet undeveloped technology, perhaps as a feed product for a fusion reactor. With this in mind, I would opt for secure above ground storage for the foreseeable future [Comment 1727, Source Document ph3pub101, Page 1]

United Church of Canada

The issues of storage/disposal/retrievability/irretrievability need to be adequately addressed from a peer-accepted scientific basis [Comment 1737, Source Document phpub124, Page 3-15, Section 3]

United Church of Canada (Cambrian Presbytery)

As research may demonstrate the viability of reducing the waste's toxicity through such processes as transmutation, retrievability is an important consideration. Moreover, it is necessary in the event of a container defect which could lead to leakage and/or deterioration. [Comment 1757, Source Document ph3pub041, Page 3]

United Church of Canada (Conference of Manitoba and Northwestern Ontario)

Storage, where materials are retrievable, has less attendant risk than disposal, should monitoring reveal signs of leakage into ground water, or, even worse, early signs of criticality. [Comment 1756, Source Document ph3pub040, Page 3]

Veterans Against Nuclear Arms (Saskatchewan Branch)

The toxicity of High Level Nuclear Waste and the extremely long period of its degradation requires that storage must be such that it can be subjected to continuous monitoring. [Comment 1761, Source Document ph3pub026, Page 1]

A proposal by John Bury of VANA for waste disposal is to keep the nuclear material in containers on the surface ... it would insure that it is well monitored. [Comment 1763, Source Document ph3pub037, Page 3]

Women of Halton Action Movement

KEEPING NUCLEAR FUEL WASTE FULLY ACCESSIBLE FOR SAFE MANAGEMENT IS OUR ONLY INTELLIGENT OPTION. [Comment 1764, Source Document ph3pub143, Page 1]

OPG RESPONSE

In 2002, OPG and the other nuclear energy corporations in Canada formed the Nuclear Waste Management Organisation (NWMO). The NWMO was established in accordance with the federal Nuclear Fuel Waste Act to investigate approaches for long-term management of Canada's used nuclear fuel. These approaches include, but are not limited to, on-site storage at reactor sites, centralised storage either above or below ground, and disposal on the Canadian Shield.

The approaches to be considered by the NWMO therefore represent a range in options with respect to monitoring, control and adaptability.

However, it is worth noting that the reference plan for a deep geologic repository (used for cost estimating purposes) has approximately 30 years of preparation, 30 years of operation, and 70 years of monitoring before repository closure. Thus, even in this option there is a minimum of 100 years of underground access and monitoring.

9.01.03 Options - Requirements - Elimination

PARTICIPANT COMMENTS

Action Against Nuclear Waste Committee

AECL needs to resolve the problem of how to detoxify its waste. [Comment 1768, Source Document phpub030, Page 3]

Concerned Citizens of Renfrew County

Claims that mined caverns will "protect human health" are false. The only way to protect health is the virtual elimination of these persistent, bioaccumulative, toxic substances. [Comment 1969, Source Document phpub171, Page 2]

Conservation Council of New Brunswick

we should invest our capital and expertise in ... the safe destruction of radioactive waste. [Comment 1997, Source Document ph3pub162, Page 5]

Durham Wetlands and Watersheds

Transmutation is not covered adequately in the EIS.... Transmutation [should] be included as the viable alternative to the creation of a NFWD Facility in a pluton given that there may be the opportunity for complete removal of the radioactivity of the waste ... potential for generations of research and jobs, and an environment free long-term radioactivity. [Comment 2000, Source Document pub043, Page 4]

Oblate Conference of Canada

We ... recommend thorough further study on how to deal with this waste, including study of avenues for actual disposal (i.e., neutralization) rather than mere storage of the waste. [Comment 1623, Source Document ph3pub213, Page 2]

Planetary Association for Clean Energy

It is imperative to examine alternatives radically less onerous in capital expenditures, presenting less risk in handling and decontamination, allowing greater fiexibility in implementation both in terms of siting and in scheduling. We are proposing such an alternative herewith: advanced transmutation. [Comment 1649, Source Document pub029, Page 05]

Saskatchewan Environmental Society

More environmentally benign ways of disposing of high level nuclear waste should still be given consideration. (Eg: transmutation) [Comment 1707, Source Document ph3pub006, Page 5]

United Church of Canada

To meet humanity's collective responsibility for the waste and its potential hazard, the more pressing issue is the need to find a safe, affordable, environmentally acceptable means of rapidly reducing the radioactivity of the waste and the quantity of waste. [Comment 1734, Source Document phpub124, Page 3-12, Section 3]

OPG RESPONSE

In the long-term, advanced reactors could reduce the amount of nuclear fuel waste produced for a given amount of power. For the present used fuel, the only option to reduce the actual radioactivity of the waste is transmutation following reprocessing and partitioning (see response to comments under Category 9.02.02). Transmutation has been examined by most radioactive waste management

organisations in the world (France and US, in particular). To date, the results of these studies suggest that transmutation would be difficult and expensive, and would not eliminate the need for a deep repository (e.g. SKB 1998).

Although there is ongoing international research, there are fundamental physical reasons why transmutation will not be achieved easily. OPG will continue to monitor this research.

Reference:

SKB 1998, RD&D Programme 98, Treatment and final disposal of nuclear waste, Programme for research, development and demonstration of encapsulation and geological disposal.

9.01.04 Options - Requirements - Recycling

PARTICIPANT COMMENTS

Earth Resources Society of Elliot Lake (Krauss and Dube)

Why don't they recycle the usable uranium before disposing of the bundles? [Comment 2016, Source Document pub002, Page 08, Section 5]

Joint Committee of the Canadian Academy of Engineering and the Royal Society of Canada

conversion of used nuclear fuel ... may not be economical now, but the possibility of reusing spent fuel should, at this stage, be an important consideration in the design of a storage facility. For example, the possible construction of a conversion plant at a site that will result in minimal cost and risk, should be part of the considerations for selecting the disposal site. [Comment 1141, Source Document tec003, Page g2]

OPG RESPONSE

Recycling of potentially useful materials in spent fuel requires chemical reprocessing (see response to comments under 9.02.03). Currently, there is an adequate supply of natural uranium for the Canadian reactors and reprocessing of spent fuel in Canada is not economic.

Even if used fuel is reprocessed, there will still be a need to manage the separated radioactive materials, together with the secondary wastes generated. The deep geologic repository concept is suitable for both used fuel and for high-level waste from reprocessed fuel.

9.01.05 Options - Requirements - Perfection

PARTICIPANT COMMENTS

Coalition for Social Justice (CHO!CES)

We know that accidents will happen sooner or later and that meand that this concept will never be "acceptably safe." [Comment 1945, Source Document ph3pub057, Page 1]

Concerned Citizens of Manitoba

Since the proponents cannot prove beyond a doubt that their concept is both safe and robust, the concept must be abandoned and work to find a safe management solution must be continued. [Comment 1959, Source Document phpub153, Page 8]

Food Irradiation Alert

The continental aquifer must not be breached. [Comment 2093, Source Document pub041, Page 1]

National Council of Women of Canada

It is necessary to be sure that the material when buried, cannot in any way affect life at the surface above the site, cannot through sorption and migration adversely affect ground waters or life forms in the ground and down stream and above all, cannot effect changes in the burial vault that will lessen its effectiveness as a barrier. [Comment 1318, Source Document phpub035, Page 03]

Northumberland Environmental Protection

A permanent solution demands failsafe guarantees ... Not one of the protective measures recommended is guaranteed permanently failsafe. [Comment 1324, Source Document phpub092, Page 01]

OPG RESPONSE

Canada, and other nations, have developed concepts for the long-term management of nuclear fuel wastes which include assessment of the safety of the concepts. It is recognised that the probability of accidents is not zero, and the deep geologic repository concept has therefore been developed based in part on consideration of possible accidents and other unlikely conditions (e.g. AECL, 1994). The current concept for the deep geologic repository is judged to be acceptably safe from a technical perspective (CEAA, 1998).

References:

AECL, 1994, Environmental impact statement on the concept for disposal of Canada's nuclear fuel waste, AECL Report AECL-10711, COG-93-1.

CEAA, 1998, Nuclear fuel waste management and disposal concept. Report of the Nuclear Fuel Waste Management and Disposal Concept Environmental Assessment Panel. Canadian Environmental Assessment Agency. Minister of Public Works and Government Services Canada. Catalogue No.: EN-106-30/1-1998E.

9.01.06 Options - Requirements - Certainty

PARTICIPANT COMMENTS

Canadian Coalition for Nuclear Responsibility (Regroupement pour la surveillance du nucléaire)

explain the importance and difficulties of proving, beyond a reasonable doubt, that any proposed disposal option would, if implemented, ensure the isolation of nuclear fuel waste from the biosphere, essentially forever [Comment 1881, Source Document pub049, Page 15]

Energy Probe (Rubin)

the object is consequence limitation, disaster avoidance, or prudence.... when we approach a task with a prudent, disaster-avoidance attitude, uncertainty is always bad, never neutral. [Comment 2131, Source Document ph2tec024, Page 6]

Groupe ecologiste de l'Universite de Moncton

La méthode proposée sera sûrement un casse-tête pour les générations futures. Elle est en fait un problème à retardement, et ceci est tout à fait inacceptable. Il est tout à fait illusoire de croire qu'enfouir les déchets radioactifs est une solution qui ne nécessitera plus d'intervention. Malgré les analogues naturels qui ont servi aux études, il est impossible de prédir exactement le comportement de tous les éléments impliqués (mouvement de l'écorce terrestre et de la nappe phréatique, des bactéries et des micro-organismes, de la radioactivité, de la chaleur, etc.).

[The proposed method will be nothing but a headache for future generations. The reliance on retardation is completely unacceptable. It is completely illusory to believe that burying nuclear waste is a solution that will not require intervention. Regardless of the studies of natural analogs, it is impossible to precisely predict the behaviour of all the components involved (movement of the earth's crust and the groundwater, bacteria and microbes, radioactivity, heat, etc.)] [Comment 2098, Source Document ph3pub237, Page 1]

Inter-Church Uranium Committee

"Especially when we lack knowledge, we have an obligation not to act. To act in ignorance is irrational." [Comment 2114, Source Document cs038, Page 1]

Inter-Church Uranium Committee (Fortugno)

The precautionary principle, an emerging principle of international environmental law, requires caution in the face of scientific uncertainty where there is a risk of human health or environmental harm.... extreme caution and prudence must govern any decisions relating to the permanent management of nuclear wastes. [Comment 2112, Source Document ph2pub031, Page 8, Section V]

Northumberland Environmental Protection

There are, however, other approaches left, when the science is still unknown: there is experimenting further. We demand that they should experiment first and proceed when they have completed the research and know what they are doing. [Comment 1505, Source Document cs028, Page 1]

because the difference in pathways could make such a huge difference to the time for contaminant to reach the biosphere, it is imperative that the METHODOLOGY USED, for pathways of groundwater flow and transport, be at lest defined and PRE-CONFIRMED before any assessment is possible. We do not know how to do this with any accuracy at all for either generic or site-specific models. This reason alone should preclude the ideas of burial in rock, as opposed to protective controlled storage in an inert medium. [Comment 1507, Source Document cs028, Page 2]

United Church of Canada

It is our understanding, however, that we have up to 100 years of storage time available in Canada. It is our judgment, therefore, that no action should be taken toward "disposal' until the time frame is much shorter and until the answers to the big scientific and ethical questions are much better. [Comment 1730, Source Document phpub124, Page 1-03, Section 1]

OPG RESPONSE

In 2002, OPG and the other nuclear energy corporations in Canada formed the Nuclear Waste Management Organisation (NWMO). The NWMO was established in accordance with the federal Nuclear Fuel Waste Act to investigate approaches for long-term management of Canada's used nuclear fuel. These approaches include, but are not limited to, on-site storage at reactor sites, centralised storage either above or below ground, and disposal on the Canadian Shield.

The approaches to be considered by the NWMO therefore represent a range from essentially the present situation - on-site storage at reactor sites - through to disposal.

However, it is worth noting that the reference plan for a deep geologic repository (used for cost estimating purposes) has approximately 30 years of preparation, 30 years of operation, and 70 years of monitoring before repository closure. Thus, even in this option there is a minimum of 100 years of underground access and monitoring.

Development of a deep geologic repository would take place in a step-wise fashion. Steps would include site identification, site investigations, detailed site characterisation, environmental assessment with further opportunities for public input, construction licence application, and operating licence application. At each approval stage, the safety assessment would be refined and updated for regulatory review.

The waste owners' work to advance the repository concept subsequent to the Seaborn Panel hearings has been built upon recognition of the need for a complementary set of arguments to support the case for safety of a deep geologic repository (NEA 1999). For example, the life time for a used fuel container is required to be at least 100,000 years (Russell and Simmons 2003).

References:

NEA, 1999, Confidence in the long-term safety of deep geological repositories. Organisation for Economic Co-operation and Development Nuclear Energy Agency Report.

Russell, S.B. and G.R. Simmons. 2003. Engineered barrier systems for a deep geologic repository in Canada. Proc. 10th International High-Level Radioactive Waste Management Conference, Las Vegas, USA.

9.01.07 Options - Requirements - Sitability

PARTICIPANT COMMENTS

Energy Probe (Brubaker)

despite the requirement to examine long-term above ground storage (Guidelines, 12), [AECL does not] analyse whether monitored retrievable storage (be it at a centralized facility or at power generation sites) would be more sitable still. [Comment 2046, Source Document pub014b, Page 08]

Risk Assessment Society

While it may have been considered that underground disposal would be more publicly acceptable, it is now apparent that opposition would be encountered whatever the options. [Comment 1423, Source Document cs011, Page 2]

OPG RESPONSE

In 2002, OPG and the other nuclear energy corporations in Canada formed the Nuclear Waste Management Organisation (NWMO). The NWMO was established in accordance with the federal Nuclear Fuel Waste Act to investigate approaches for long-term management of Canada's used nuclear fuel. These approaches include, but are not limited to, on-site storage at reactor sites, centralised storage either above or below ground, and disposal on the Canadian Shield, based on the AECL concept.

Currently, the waste owners believe that there is the potential for suitable sites in Canada for either storage or disposal (for example, see Everitt 1999). The issue of specific siting for the government-selected approach will be addressed after the government decision.

Reference:

Everitt, R. 1999. Experience gained from the geological characterisation of the Lac du Bonnet batholith, and comparison with other sparsely fractured granite batholiths in the Ontario portion of the Canadian Shield, OPG Report 06819-REP-01200-0069-R00.

9.01.08 Options - Requirements - Canadian Location

PARTICIPANT COMMENTS

Energy Probe (Brubaker)

[AECL] doesn't explore the possibility of exporting waste to a volunteer community south of the border. That option it dismisses without any discussion of the provisions of the Free Trade Agreement or examination of whether Canada's waste would be welcome in an American MRS facility [Comment 2048, Source Document pub014b, Page 11]

Global Citizens Forum

Nuclear waste should be managed where it is produced. There is a national responsibility for the disposal of radioactive wastes produced in any one country. Transboundary movement of radioactive wastes is not acceptable. [Comment 2094, Source Document ph3pub022, Page 1]

Ligue des femmes du Québec

Quant au stockage à long terme, le diagnostic, les tests et les solutions doivent tenir compte d'un plan continental nord-américain. Cela nous semble évident pour un projet d'une durée exceptionnelle. [As for long-term disposal, the diagnostic tests and solutions must take into account a North American plan. This seems logical for such an exceptionally long-lasting project.] [Comment 1468, Source Document phpub034, Page 0]

OPG RESPONSE

The government of Canada sets national policy on the management of radioactive wastes in Canada (NRCan 1996).

Reference:

NRCan 1996. Government of Canada announcement on the policy framework for radioactive waste.

9.01.09 Options - Requirements - Current Location

PARTICIPANT COMMENTS

Action Against Nuclear Waste Committee

if the containment method planned by AECL is as safe as suggested, there is no reason why the spent fuel and other waste cannot be kept in above ground storage in sites close to the nuclear plants generating the waste, thus also avoiding the problems related to transportation. [Comment 1769, Source Document phpub030, Page 3]

Atikokan Citizens for Nuclear Responsibility

Dr. Resnikoff, a leading expert in dealing with radioactive waste has suggested that the present method employed by Ontario Hydro is by far the best way in which to store waste of this type over the long term. It can be monitored, it is retrievable, it doesn't have to be moved, it is more economic, it is a reminder of the garbage that is produced, and the people who benefit directly from nuclear power have to deal with it. [Comment 1774, Source Document ph3pub076, Page 4]

Canadian Voice of Women for Peace

leave the waste in continuously monitored storage at or close to the site of the production of the waste. [Comment 1921, Source Document cs023, Page 2]

Citizens Environment Alliance

There are ample storage systems that will last for decades and are conveniently located in the near vicinity of the locations that generate the actual nuclear waste.... burial of nuclear fuel wastes in the Canadian Shield is unnecessary and premature. [Comment 1940, Source Document ph3pub141, Page 1]

Citizens for Renewable Energy

NO disposal of Nuclear Waste - just ON SITE STORAGE [Comment 1944, Source Document cs040, Page 2]

We urge the Panel to reject the deep burial concept and recommend above ground storage instead, where waste is created and where it must be closely monitored [Comment 1943, Source Document ph3pub124, Page 3]

Conservation Council of New Brunswick

the safest, most responsible course of action is to store the waste on site in carefully designed and monitored, secure, above ground structures. We should keep this most deadly substance created by humans well within our view rather than putting it out of sight. [Comment 1996, Source Document ph3pub162, Page 5]

Earth Resources Society of Elliot Lake (Krauss and Dube)

The present way of storage is right in the middle of a high density population. [Comment 2020, Source Document pub002, Page 08, Section 5]

Ligue des femmes du Québec

La sécurité du public doit primer sur tout. A cet égard, la situation immédiate est extrêmement inquiétante. L'entreposage des déchets de combustible nucléaire sur les sites des centrales n'est pas protégé adéquatement contre les attaques des terroristes et des malfaiteurs et cela est inadmissible. [Public security must take precedence over everything else. For this reason, the current situation is extremely disturbing. Disposing of nuclear fuel waste on station sites is not safe enough from terrorist attacks and lawbreakers, and this is unacceptable.] [Comment 1467, Source Document phpub034, Page 0]

Nipissing Environmental Watch

We support further research into better methods at the existing sites. How about neutralization? How about alternative ways that don't involve transport? [Comment 1499, Source Document ph3pub100, Page 1]

Northwatch (Richardson)

What appears to be missing ... from AECL's treatment of the alternatives to geological disposal on land ... is any mention of the so-called Zero-Option, which entails storing the material on-site at the place of production or at a central facility. [Comment 1554, Source Document ph3pub088, Page 02, Section 2]

Oblate Conference of Canada

In the interim, we ask this panel to recommend that the waste continue to be stored on the sites where it is produced [Comment 1624, Source Document ph3pub213, Page 2]

United Church of Canada (Conference of Manitoba and Northwestern Ontario)

We see insufficient attention having been given to on-site, long-term storage options. [Comment 1755, Source Document ph3pub040, Page 2]

Veterans Against Nuclear Arms (Saskatchewan Branch)

To this end we propose that the sites be visible and near large centres of population so that their presence cannot be ignored. The waste should stay as near its present position as possible to avoid the dangers of long distances of transportation, as far as this allows for it to be sited near a major centre of population. [Comment 1762, Source Document ph3pub026, Page 2]

OPG RESPONSE

In 2002, OPG and the other nuclear energy corporations in Canada formed the Nuclear Waste Management Organisation (NWMO). The NWMO was established in accordance with the federal Nuclear Fuel Waste Act to investigate approaches for long-term management of Canada's used nuclear fuel. These approaches include, but are not limited to, on-site storage at reactor sites, centralised storage either above or below ground, and disposal on the Canadian Shield.

Continuation of the present situation - i.e. on-site storage at reactor sites - is explicitly being considered.

9.01.10 Options - Requirements - Cost Comparison

PARTICIPANT COMMENTS

Canadian Radiation Protection Association

The facility will be extremely expensive. There does not seem to a reasonable balance between these obvious costs and the questionable far-removed benefits to a future hypothetical and presumed chaotic society. The risks that should be addressed in considering disposal of high level waste should be those that are defined for present-day society. Making assumptions of the character of society far into the future and allocating resources based upon those assumptions is not only illogical it is irresponsible.... Over-allocation of resources to address hypothetical, trivial risks that are unjustifiably extrapolated far into the future, should be strongly resisted. These are judgements that we have neither the ability to make, nor the justification to assume. [Comment 1106, Source Document ph3pub045, Page 4, Section 4]

Chemical Institute of Canada

the cost or cash flow must surely be a factor in selecting between disposal options - given that risk management criteria are met. [Comment 1132, Source Document tec005, Page 27, Section IV.ii.3]

Energy Probe (Rubin)

it may be illustrative for AECL to present some estimates of the cost of building a 500-year monitorable intrusion resistant storage facility for up to about 3 million bundles of spent fuel [Comment 2084, Source Document ph2tec024, Page 8]

Nuclear Awareness Project

Future research and development costs, and costs associated with extended on-site storage need to be evaluated in the context of the burial options presented so far. [Comment 1615, Source Document ph3pub138, Page 4]

Risk Assessment Society

We are concerned with the expense that this project represents versus the benefit to public safety that it will provide. In simple terms, are we spending too much money on addressing the nth degree of safety and engineering on the disposal of nuclear wastes when a much lower level of expenditure would produce almost as good results at a much lower cost and would leave surplus funds which could be devoted to areas where much higher known safety risks exist. [Comment 1421, Source Document ph3pub175, Page 3]

If an underground nuclear waste repository costing \$15 billion were not required by law and instead a \$2 billion surface storage facility were built for nuclear waste, the difference of \$13 billion need not be taken from the public via higher electricity rates, or if it was taken, this \$13 billion might be applied to stimulate the creation of safer products, to detect cancer early with increased pap smears, clinics to help smokers overcome their additions, improved road safety, etc. [Comment 1422, Source Document ph3pub175, Page 4]

Robertson, J.A.L.

In any discussion of alternatives it is desirable to make explicit a criterion for selection between them. In several submissions to the Panel's Scoping Hearings there was an implicit assumption that the criterion should be "the best".... there are ... good reasons for rejecting this as a criterion: "... devoting limited resources to make one technology much safer than others leaves less to tackle the real problems. Thus the 'best possible' solution in one area may not yield the 'best possible' solution overall." [Comment 1451, Source Document phpub004, Page 10]

OPG RESPONSE

In 2002, OPG and the other nuclear energy corporations in Canada formed the Nuclear Waste Management Organisation (NWMO). The NWMO was established in accordance with the federal Nuclear Fuel Waste Act to investigate approaches for long-term management of Canada's used nuclear fuel. These approaches include, but are not limited to, on-site storage at reactor sites, centralised storage either above or below ground, and disposal on the Canadian Shield.

The NWMO assessment of the options will consider cost estimates for these approaches.

Options - Alternatives to Disposal

9.02

9.02.01 Options - Alternatives to Disposal - Storage

PARTICIPANT COMMENTS

Campaign for Nuclear Phaseout

What are the implications of extended above-ground storage? What is the impact of extended dry storage on the integrity of the used fuel bundles? [Comment 1805, Source Document pub027, Page 26, Section III.E]

Canadian Coalition for Nuclear Responsibility (Regroupement pour la surveillance du nucléaire)

If containers can be designed that are sufficiently sturdy and reliable, then geologic disposal may be unnecessary, as surface containers may be sufficiently resistant to external forces. [Comment 1910, Source Document cs031, Page 03]

specify possible mechanisms that might lead to a failure of current containment methods due to a lack of adequate institutional controls [Comment 1880, Source Document pub049, Page 15]

Earth Resources Society of Elliot Lake (Krauss and Dube)

If existing power plants will be outdated by the year 2025, what will happen to fuel bundles being stored now? ... Will heavy water pools still be in place after closure of nuclear generating plants? [Comment 2025, Source Document pub002, Page 10, Section 6]

People Against Lepreau 2

Research & develop improved methods for surface storage of spent nuclear fuel. [Comment 1641, Source Document ph3pub154, Page 13]

United Church of Canada

More investigation needs to be done on retrievable monitored storage options. [Comment 1749, Source Document phpub124, Page 3-34, Section 3]

The alternatives of long-term above ground and underground storage ... are not discussed in sufficient detail. [Comment 1752, Source Document phpub124, Page 3-46, Section 3]

OPG RESPONSE

In 2002, OPG and the other nuclear energy corporations in Canada formed the Nuclear Waste Management Organisation (NWMO). The NWMO was established in accordance with the federal Nuclear Fuel Waste Act to investigate approaches for long-term management of Canada's used nuclear fuel. These approaches include, but are not limited to, on-site storage at reactor sites, centralised storage either above or below ground, and disposal on the Canadian Shield.

OPG and the other Canadian waste owners are presently moving fuel bundles from the on-site water storage into on-site surface dry storage containers. In support of the NWMO investigation, the waste owners are conducting studies on the possible lifetime of surface dry storage facilities for used nuclear fuel. We presently estimate that the service lifetime of a concrete/steel-based surface dry storage container housed in a building is approximately 100 to 300 years.

9.02.02 Options - Alternatives to Disposal - Transmutation

PARTICIPANT COMMENTS

Canadian Coalition for Ecology, Ethics and Religion

Research is necessary to evaluate the application of various transmutation system concepts to significantly reduce the quantity of high-risk waste; the radiation hazard of the waste over the short and long terms; the security threat with regard to bomb production; and the chemical availability of the waste in a geological repository under different scenarios. The theoretical, technical, and economic factors limiting progress into the transmutation option need to be made clear. [Comment 1845, Source Document phpub043, Page 40, Section 15]

Citizens Environment Alliance

In the meantime, more research should be undertaken for transmutation. [Comment 1941, Source Document ph3pub141, Page 1]

Coalition for Social Justice (CHO!CES)

research into actual methods of disposal, such as transmutation or plasma based fusion should begin. [Comment 1946, Source Document ph3pub057, Page 1]

Coalition pour la surveillance du nucléaire (COSUN)

"ATW (Accelerator Transmutation of Waste) could change the basic nature of the waste storage problem: storage for 10,000 years or more to storage for only a few hundred years or less, thereby shifting the burden of radioactive waste containment from geological repositories to engineered containers."... we cannot continue to overlook technologies which might offer those kinds of benefits. [Comment 1274, Source Document phpub136, Page 5]

Dr. Charles D. Bowman ... "...a new accelerator-based nuclear technology which offers total destruction of the weapons plutonium inventory, (and) a solution to the commercial nuclear waste problem which greatly reduces or perhaps eliminates the requirement for geological waste storage..." This reviewer has called attention to one kind of advanced technology that may have already eclipsed the permanent underground storage option. Serious consideration, with equivalent studies and expenditures must be given to the in-depth investigation of this, as well as other alternative possibilities. [Comment 1271, Source Document pub011, Page 08]

it is recommended that ... Those who have responsibility for the safe management of used fuel--the Federal Government and the owners of the used fuel, in consultation with the public, undertake a comprehensive examination of alternatives to underground isolation (with special emphasis on above-ground, long-term, on-site dry storage, coupled with accelerator-driven transmutation technology). [Comment 1272, Source Document pub011, Page 11]

Durham Wetlands and Watersheds

More discussion is needed of recycling and incineration by lasering of nuclear fuel waste. [Comment 2009, Source Document pub043, Page 5]

International Institute of Concern for Public Health (Bertell)

There are also possibilities of transmutation of waste into non-radioactive byproducts. These possibilities are also being closed out by the AECL proposal.... I do not advocate that Canada become involved in nuclear reprocessing in order to facilitate transmutation. [Comment 2124, Source Document ph3pub105, Page 1]
Planetary Association for Clean Energy

Brown's Gas has been developed by a Bulgarian-born Australian national, Prof. Yull Brown.... Some units have been used for the decontamination of radioactive materials since 1991.... Prof. Brown first successfully de-radioactivated radionuclides of Cobalt 60 in his laboratory in Sydney, Australia with first experimental results of about 50%.... Brown has seen the various stages of his gas offer very different effects. He has found that he can modulate a number of suitable mixes for his technology, thus providing an engineering tool in decontamination of nuclear wastes. [Comment 1650, Source Document pub029, Page 13]

A recent investigation ... involved a modified Caduceus coil.... the field from this set-up was able to decrease ambient radioactivity associated with environmental isotopes from 0.5 mR/hour to 0.001 5 mR/hr -- or by 97%. [Comment 1651, Source Document pub029, Page 15]

Another non-Hertzian approach to advanced transmutation has been hypothesized by the nuclear scientist, Tom E. Bearden and involves the use of "Whittaker scalar interferometry" directed in such a way as to directly extract electromagnetic energy from the mass of the radioactive nuclei.... By exposing the atomic nucleus to an externally engineered Whittaker-structured potential with a deterministic internal electromagnetic wave pattern, the internal structure of the mass potential may be slowly altered, changing the targeted atomic nucleus by gradually inducing a direct alteration of its internal Whittaker electromagnetic bi-wave composition. [Comment 1652, Source Document pub029, Page 16]

Saskatchewan Environmental Society

There has been a little discussion, for example, of the possibility of eventually using accelerator-based transmutation as a way of converting long-lived radioisotopes to stable or shorter-lived ones. [Comment 1709, Source Document ph3pub010, Page 2]

Scientific Review Group

transmutation of the radioactive isotopes is [not] practical under present technological and economic conditions [Comment 324, Source Document tec004, Page 021, Section 3]

United Church of Canada

transmutation system concepts have the potential to significantly reduce the quantity of high risk waste, the radiation hazard and the security threat with respect to bomb production. The theoretical, technical or economic factors that are limiting the progress in the transmutation option should be presented to the public. [Comment 1753, Source Document phpub124, Page 3-47, Section 3]

there [should] be support for research to find a means of interaction with radioactive nuclei to move the nuclei to a more stable state over time scales which are accelerated over those by the natural decay process. [Comment 1754, Source Document phpub124, Page 3-47, Section 3]

OPG RESPONSE

In 2002, OPG and the other nuclear energy corporations in Canada formed the Nuclear Waste Management Organisation (NWMO). The NWMO was established in accordance with the federal Nuclear Fuel Waste Act to investigate approaches for long-term management of Canada's used nuclear fuel.

Transmutation was discussed briefly in AECL's EIS, but is not seen as a currently-feasible concept. OPG has reviewed the status of transmutation, and is monitoring developments in other countries.

Studies in the 1970s concluded there was no cost or safety incentive to pursue transmutation, however, major programmes of research on partitioning and transmutation (P & T) are now being pursued in several countries, notably the US program of R&D in Accelerator Transmutation of Waste

(ATW), accompanied by programmes of international co-operation and technology exchange, fostered by the Nuclear Energy Agency of OECD (NEA) and the European Commission (EC).

Prior to transmutation, the used fuel which contains the long-lived radionuclides must be reprocessed. Reprocessing is already carried out in a number of countries as a method of used fuel management, and to make the uranium and plutonium in the used fuel available for re-use (see also response to Category 9.02.03). Further development is needed to enable separation of the radionuclides of interest in P & T. Transmutation systems potentially include thermal reactors, fast reactors, and accelerator-driven systems. Research of the effects of introducing transmutation on the safety and operation of these systems is required. Accelerator-driven systems are at present only a concept, although considerable research is in progress in the US and other countries. Introduction of P & T would also raise a number of problems in fabrication and recycling of targets.

The transmutation cycles currently envisaged, involving destruction of the minor actinides and the very long-lived fission products, would not eliminate the need for a geological repository for the remaining waste. This waste would consist of the remaining fission products in the HLW, and possibly process wastes containing small amounts of all the original constituents, depending on the decontamination factors achieved in reprocessing and recycling.

The reduction in very long term hazard from mobile fission products might affect the design of the repository and the requirements placed on the engineered barriers. Removal of the minor actinides would not affect this long term hazard, but would reduce the hazard from intrusion scenarios.

The potential costs appear to be very large in comparison with estimated costs for permanent isolation of unreprocessed used fuel. At present both benefits and costs are uncertain. Advanced transmutation concepts require a breakthrough in technology development and a large research effort.

9.02.03 Options - Alternatives to Disposal - Reprocessing PARTICIPANT COMMENTS

Campaign for Nuclear Phaseout

An EIS on post-reprocessing waste should include a discussion of radioisotopes released at all stages of the reprocessing cycle; an analysis of the composition of post-reprocessed materials and its radiological characteristics; exposures of workers and the public to radiation from a reprocessing plant - alone, and as part of a facility which included a high level waste repository; the security and environmental implications of siting a reprocessing plant in proximity to a high level waste storage facility; the potential for chemical explosions and criticality accidents at such a plant; radioactive emissions in air, water and effluent; the disposition of contaminated equipment; the record of safety at reprocessing plants. [Comment 1781, Source Document pub027, Page 16, Section III.B]

Canadian Coalition for Nuclear Responsibility (Regroupement pour la surveillance du nucléaire)

The proponent defines nuclear fuel waste to mean either used nuclear fuel or solidified high-level liquid waste from reprocessing. Accordingly, failure to describe the environmental, social, and political impacts of reprocessing, and the possible implications for a nearby nuclear fuel waste repository, constitutes a glaring and unacceptable omission ... provide a thorough discussion of reprocessing technology, describing all radionuclides released ... environmental and safety records ... environmental and safety implications ... security and other socio-political implications ... accident analysis ... quantities and disposal of contaminated equipment ... handling of waste water ... the characteristics and behaviour of solidified post-reprocessing nuclear fuel waste in comparison with the characteristics and behaviour of irradiated UO2 fuel in the vault and geosphere environments. [Comment 1875, Source Document pub049, Page 09]

Pacific Institute for Advanced Study

small amounts of chemically compatible radioactive material could be bound into the crystal lattices of certain metamorphic rocks. Since the radioactive atoms would form only a small fraction of the component material, radiation damage to the crystal lattice would be expected to be minimal and the solid solutions would be able to retain the foreign atoms even after transmutation takes place.... The necessary knowledge of solid state chemistry and mineralogy is available to predict the behaviour of substitutionals within crystal lattices.... One possible mineral for fixing radioactive 137C is Leucite (KALSi206); the cesium can be easily substituted for the potassium and the resulting composite material has very low solubility and a very high melting point. Sphene (CaTiSi05) will accept 90Sr for a replacement of the calcium and it seems very likely that several other substitutions will be accepted into the crystal structure. Pervskite (CaTi03) will accept 99Tc in the titanium site while Fresnoite (Ba2TiSi208) will accept elements of similar atomic size, so would be capable of immobilizing 1291, among many others. It is certain that determined experimentation can yield minerals that could fix every possible radio-isotope found in nuclear waste ... Radiation damage caused by element transmutation can be controlled by reduction of the concentrations of radioactive material seeded into the crystal lattice.... Once the radioactive waste is fixed into a crystal material, the whole lot could then be safely placed into containers and then buried in deep shafts dug into large intrusive formations. [Comment 1447, Source Document phpub006, Page 3]

OPG RESPONSE

Currently, there is an adequate supply of natural uranium for the Canadian reactors and reprocessing of spent fuel in Canada is not economic. Therefore, the present reference plan of OPG and the other Canadian waste owners is to manage used fuel without reprocessing.

The NWMO is considering the options for long-term management. A management method which included reprocessing would require an assessment of the implications.

9.03 Options - Alternative Disposal Media

PARTICIPANT COMMENTS

Campaign for Nuclear Phaseout

dumping in Canada's territorial waters is not clearly ruled out. [Comment 1794, Source Document pub027, Page 24, Section III.D]

Canadian Coalition for Ecology, Ethics and Religion

With continued interest in subduction and various other options elsewhere, the public is left wondering why these concepts have been dismissed in Canada. [Comment 1843, Source Document phpub043, Page 38, Section 15]

Canadian Geoscience Council

The alternate sites are of two levels: either deep, (i.e., in the water-saturated zone) or high (in the vados or unsaturated zone), and of three types: salt, shale, and shallow crystalline rocks (i.e., the surficial rocks of the Canadian Shield). These sites are summarized in Table 1 in Appendix A. Most have problems of expense ... or hazard ... the focus on deep burial in the plutonic rocks of the Canadian Shield is still a (the) most reasonable option [Comment 1082, Source Document tec002, Page 13, Section 3.1.2]

Canadian Geotechnical Society

the CGS supports the search for a candidate repository site in plutonic rock. Salt and shale can also be suitable host media, but should only be considered if future studies of plutonic rock sites encounter concerns which are much more severe than presently expected. [Comment 1264, Source Document pub020, Page 11]

The CGS agrees with AECL that with the current available geological information, the numerous plutons in the extensive Canadian Shield are the most suitable geological medium for safely isolating nuclear waste to perpetuity.... some baseline data on other geological media such as salt or shale should be available for making appropriate comparisons of alternative disposal media. [Comment 1084, Source Document pub020, Page iii]

Joint Committee of the Canadian Academy of Engineering and the Royal Society of Canada

There is a lack of information which would place AECL's work within the context of parallel national and international studies of nuclear waste disposal. The EIS supplies an outline of other disposal concepts and the approaches being studied in other countries... but offers little or no comparative data by which the AECL solution can be assessed against developments elsewhere, in terms of apparent safety and stability or comparative cost. [Comment 1135, Source Document tec003, Page sgw1]

alternatives are only mentioned very briefly (Ref.1, p.321). I would have liked to have seen a summary of the rock types selected for sites in other countries in order to have a perspective on how many sites are in plutonic rock, bedded salt, shale etc. Is there evidence elsewhere of successful siting in other than plutonic rock? The fact that plutonic rock is prevalent in Ontario does not necessarily qualify it as the best technical choice. [Comment 1143, Source Document tec003, Page w02, Section 2]

Northwatch

the EIS should provide a comparison of plutonic rock to non-plutonic rock (ie. other rock forms or types) and provide information to substantiate the selection of plutonic rock over non-plutonic rock [Comment 1390, Source Document pub046, Page 18, Section d]

Northwatch (Richardson)

By dismissing other possible host rocks out of hand, AECL are removing the possibility of being able to make useful comparisons of potential repository performance at a possible future licensing stage [Comment 1555, Source Document ph3pub088, Page 04, Section 3.1]

OECD/NEA Review Group

Given the extent of the Canadian Shield, spreading the net wider to look at other geological formations could be counterproductive in that it dilutes effort. We also point out that, for many years, international opinion has been that it is not possible to define the 'best solution'; it is simply necessary to find and demonstrate a clearly acceptable solution with adequate margins of safety. The Group can see no technical reason to suggest that other geological options need to be evaluated in Canada. On the other hand, given the long time scale for final implementation of the concept, it would be prudent to continue studies of engineering barriers concepts, including alternatives. [Comment 1257, Source Document tec001, Page 20, Section 6.2]

Scientific Review Group

it is appropriate, on a technical basis ... for Canada to choose land-based disposal, and to choose plutonic rock of the Canadian Shield, ... as the host medium for the development and demonstration of a nuclear fuel waste disposal system [Comment 325, Source Document tec004, Page 021, Section 3]

if necessary, thick shale deposits or salt deposits also might be evaluated as suitable host materials for geological disposal of Canada's nuclear fuel waste [Comment 326, Source Document tec004, Page 021, Section 3]

OPG RESPONSE

Research conducted during the Canadian Nuclear Fuel Waste Management program has provided technical and scientific evidence that long-term isolation of used fuel waste is achievable within an engineered repository at suitable depths within the rock of the Canadian Shield. Alternative geologic media, such as evaporites, clays and carbonates have not been as thoroughly assessed in Canada.

However, it is known that Phanerozoic (570 million years ago to present) sedimentary sequences exist in Canada with thick, low permeability formations that may be suitable to host a used fuel repository. Internationally, efforts in the past 5 years have also begun to focus on sedimentary media, most commonly clays. Examples are the Belgium Mol clay research facility, the Swiss Opalinus clay (shale) research area, and the French underground research facility in clay (argillite) at the Haute-Marne site.. A re-examination of alternative geologic media to host a used fuel repository has been initiated so that there is sufficient information for an assessment of the options.

The work of the NWMO has included review of a wide range of options, and a survey of options being considered in other countries.