NUCLEAR WASTE MANAGEMENT ORGANIZATION
SOCIÉTÉ DE GESTION DES DÉCHETS NUCLÉAIRES

June 2004

NWMO BACKGROUND PAPERS
6. TECHNICAL METHODS

6-10 REVIEW OF CONCEPTUAL ENGINEERING DESIGNS FOR USED NUCLEAR FUEL MANAGEMENT IN CANADA (FINAL REPORT)

ADH Technologies Inc.

NWMO Background Papers

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

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

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

ADH Technologies Inc.
"Bringing Innovation to Market"

Review of Conceptual Engineering Designs for Used Nuclear Fuel Management in Canada (Final Report)

Prepared for

Nuclear Waste Management Organization (NWMO)

By

ADH Technologies Inc.

June 4, 2004

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GLOSSARY OF TERMS:

AECL	Atomic Energy of Canada Limited
CES:	Centralized Extended Storage
CRC:	Casks in Rock Caverns
CSB:	Casks in Storage Buildings
CST:	Casks in Shallow Trenches
CVSB:	Casks and Vaults in Storage Buildings
CVST:	Casks and Vaults in Shallow Trenches
DGR:	Deep Geologic Repository
HQ	Hydro Quebec
JWO:	Joint Waste Owners
NBP	New Brunswick Power
NFWA	Nuclear Fuel Waste Act (the “Act”)
NWMO	Nuclear Waste Management Organization
OPG	Ontario Power Generation
RES:	Reactor Site Extended Storage
SSB:	Silos in Storage Buildings
SST:	Silos in Shallow Trenches
SMV:	Surface Modular Vault
UFC:	Used Fuel Container
UFPP:	Used Fuel Packaging Plant
UFTS:	Used Fuel Transportation System
VST:	Vaults in Shallow Trenches

1.0 Executive Summary:

The Nuclear Fuel Waste Act (NFWA) requires the NWMO to submit a report to the Government of Canada which includes comparison of costs, risks and benefits of at least three approaches for managing Canada's nuclear fuel wastes over the long-term.

In advance of the NWMO being established, Ontario Power Generation, Hydro-Québec, AECL and New Brunswick Power (the "Joint Waste Owners") – anticipating their responsibilities under the NFWA to establish the NWMO and to ensure that a comprehensive study is completed within the legislated timelines – commissioned work to develop conceptual designs for the options in the then draft NFWA.

Specifically, the Joint Waste Owners commissioned some studies in 2001 and 2002 based on the anticipated requirements in the Act, prior to the establishment of the NWMO. These studies concerned the development of technical descriptions for the alternative approaches and associated cost estimates for three technical methods for long term management of used fuel. In particular, they developed conceptual designs for the technical methods set out in the Act, and the associated cost estimates.

The Joint Waste Owners presented this body of work to the NWMO at the end of 2003, for use in the NWMO's study of used fuel management approaches.

Conceptual designs were prepared by the Joint Waste Owners for the following approaches to used fuel management:

- Deep Geologic Repository (DGR)
- Reactor Extended Storage (RES)
- Centralised Extended storage (CES)

In addition, conceptual design information was developed for transportation systems that would be required for design options that use centralized facilities (i.e. DGR and CES).

A key assumption was that the total amount of used fuel bundles to be managed is 3.6 million. A set of reports and CDRoms consisting of design information have been provided that document the assumptions used and conceptual design details.

The NWMO made a decision that it would invite a third-party review of the conceptual designs to validate the engineering process used in their preparation. This review and validation by a qualified third party was seen as necessary to provide the NWMO with the assurance of the integrity of the design work. The NWMO felt it particularly important to ensure that the designs have been developed in a manner consistent with established industry standards and practice. The purpose of this present review is to give confidence to the users of the design information that it is reliable and can be used for the intended purpose of assessing and comparing the relative merits of the given approaches.

Accordingly, in April 2004 the NWMO launched a third-party review of the conceptual design engineering process used by the Joint Waste Owners. The NWMO engaged ADH Technologies Inc. to undertake this review.

The focus of this project was to review and validate the conceptual design process and to comment on the underlying assumptions. In addition, the review was to comment on the flexibility to adapt the design as assumptions and circumstances change in the future.

The NWMO set out seven specific criteria for validation as follows:

1. *Document the process and assumptions used by the Joint Waste Owners to develop the conceptual designs for each method.*

2. *Comment on how each method has been described to account for possible future changes in the volume of fuel used and other key related assumptions.*

3. *Comment on the extent to which the conceptual designs adequately describe the technical methods that the NWMO must study as outlined in Section 12 of the NFWA.*

4. *Comment on the extent to which the conceptual designs for each method have taken into account "natural and other events that have a reasonable probability of occurring" as described in Section 13 of the NFWA.*

5. *Map the document trail that supports the conceptual designs, assess the documentation and comment on the quality and completeness of the documentation.*

6. *Document how accepted engineering standards were followed in the development of the various conceptual designs.*

7. *Deliver a signed opinion on the processes and standards that were followed in developing the conceptual engineering designs and the extent to which the descriptions of the conceptual designs for each method adequately meet the requirements of the NFWA.*

The reviewers undertook an extensive review of the conceptual designs provided and arrived at an assessment against each the criteria listed above. These specific assessments are set out in Section 6 of this report.

The team also arrived at an overall assessment and conclusion concerning the conceptual designs which is summarized as follows:

The conceptual designs are assessed to be suitable for the intended purpose which is to assess the options presented and arrive at a recommended approach. The conceptual designs are well developed and documented and prepared in a manner consistent with established engineering practice.

Accordingly, it is reasonable to expect that any of the options reviewed could be developed into a full detailed-design that would meet the requirements of the NWMO program. It should be noted however, that should there be a requirement to accommodate non-standard fuels, the designs would have to be adapted to address such a need. It is reasonable to expect that this could be done within the overall design concepts presented although there would be an impact on the overall system design and program cost.

2.0 Background:

Over the past two decades much work has been undertaken in Canada regarding the development of technologies and approaches for the long term management of used fuel. These programs have resulted in a large database of information and technology that is available to the NWMO for its deliberations. Among the various programs undertaken are:

- The AECL program to develop the Deep Geologic Repository (DGR) technology that was undertaken in the 1980's and early 1990's. This technology and program were the subject of detailed environmental assessment in the mid-1990's culminating with the Seaborn report.

- The development of technology for on-site storage of spent nuclear fuel in canisters systems or concrete monoliths. Systems of this kind developed by Ontario Power Generation and AECL respectively are in use on CANDU reactor sites in Canada and abroad.

Various other programs and approaches have been considered over the years in the development of the Canadian nuclear power program. There is also considerable international experience in the development of such technology and programs that have emerged as various countries establish their own policies and methodologies for management of spent nuclear fuel.

The NWMO has commissioned the present third-party review to validate the process and assumptions used to develop conceptual designs for certain options for the long term management of spent nuclear fuel in Canada. The conceptual designs were developed by the Joint Waste Owners and were completed in December of 2003.

The conceptual designs produced are:

- Deep geologic disposal in the Canadian shield
- Storage at nuclear sites
- Centralised storage, either above or below ground
- Retrieval of waste from storage and transportation to a deep geologic repository or centralised storage facility.

The conceptual design for transportation of the nuclear fuel waste, where applicable, to a final location, has been provided by Cogema Logistics. Cogema Logistics is a French company with extensive experience in transportation of nuclear fuel waste in Europe.

The conceptual design information for siting, design, construction, operation, extended monitoring, closure and decommissioning of the waste management facilities was provided by CTECH. At the time the designs were developed, CTECH was a joint venture of CANATOM (SNC-Lavalin, AECON) and AEA Technologies (UK) (now RWE Nukem).

The review and validation of the conceptual designs is important to provide assurance to the NWMO of the integrity of the work. The NWMO engaged the services of ADH Technologies Inc. to undertake this review.

ADH Technologies Inc. is a well known management consulting and project management firm engaged in the nuclear industry. The firm provides specialized services advising clients in the nuclear sector in the fields of project management, project cost estimating, engineering, and business development. The company is founded and lead by individuals that have more than 25 years experience in the Canadian and international nuclear industry at the executive level. In particular, the company is experienced in the development and management of major nuclear projects up to the billion dollar range. The company also has extensive experience in project management of large industrial projects. The company is familiar with both government and private-sector practices relating to large projects.

ADH Technologies Inc. has recently completed third-party review work, on behalf of the NWMO, regarding the validation of the process used in estimating the costs of these options. In the course of this work, the company developed a good appreciation of the NWMO and its requirements, and in particular, a comprehensive understanding of the proposed technical design concepts.

3.0 The Review Team

ADH Technologies Inc. assembled a team of experts experienced in the nuclear sector to undertake the review. ADH Technologies Inc. also maintains a network of associates who are expert in the nuclear industry and have held a wide range of positions – ranging from roles in engineering and design of such facilities, through project management, to executive roles managing nuclear industry organizations.

The resources assembled to undertake the work are qualified engineering and nuclear waste management specialists. They have had direct responsibility for such reviews in the past and have held program responsibility for engineering and project management of projects of similar scope and complexity to those options under consideration by NWMO. Resumes of the individuals who had primary responsibility and who performed the work are included in Appendix 1.

4.0 Methodology

ADH Technologies Inc. has recently undertaken related work regarding the review of the estimating process for the same three design concepts, including transportation aspects, which enabled the team to build upon this experience. In the course of the earlier work, the company undertook a review of the conceptual design information and data, in order to establish the basis for the work breakdown structure used in deriving the estimates. This enabled key team members to develop a familiarity with the design concepts and technical information. For the review of the conceptual designs, the company used the same individuals in the performance of the present work – augmented by specialist expertise in the field of nuclear waste management.

In developing conceptual designs, qualified engineering organizations typically follow a standard design process. This process normally involves the establishment of initial design specifications and requirements; development of conceptual design documents; followed by peer-review of the designs through an internal process; and finally formal issue of the design documents after checking, review, and approval.

The approach used by the review team involved a detailed review of the conceptual design information previously supplied, which is quite comprehensive, followed by assessment of the assumptions and design process used by the Joint Waste Owners. This enabled the reviewers to establish the appropriateness of the engineering processes applied in developing the design concepts. ADH Technologies Inc. use of a specialist, who has domestic and international experience with nuclear waste management technology, programs, and issues, was instrumental in validating the assumptions that form the basis of the designs.

In the course of the review of the documents, the team developed a map of the documentation trail that supports the designs and prepared a report on its findings.

4.1 Process Applied

As a first step, the team acquired and read the documents in order to gain an overview understanding of the content and to familiarize itself with the information. This review was followed by a series of discussions among team members to assess the strengths and weaknesses in the information and to confirm the review approach.

Following on from the discussions the team also began the process of "mapping" the data. This involved reviewing all the documentation provided and establishing a format that gives an overview of the documentation and information structure.

The document packages included estimates for three different approaches for the long-term storage and disposal of used fuel. Within each concept there may be multiple alternatives, each with their own design, or alternatively, there may be multiple sites applying a particular approach which result in specific conceptual designs for each site.

In cases where the approaches require shipping of the used fuel between sites, there are separate designs of the transportation and handling systems that need review.

Finally, the review team undertook a review of the underlying assumptions that were applied in developing the designs. This was necessary to ensure that the designs are adaptable for future changes to quantities and types of spent fuel. Overall, comments about the design documentation and the assumptions were assembled into a report to the NWMO based on the initial criteria.

5.0 General Findings

The scope of the third-party review included an investigation and a validation of the process and assumptions used to develop the conceptual designs for the three methods and associated transportation requirements. This included a review of all of the engineering designs (geological disposal, centralized storage, reactor site storage) plus related transportation facilities and logistics. It also included an examination of the assumptions used in the design/development of each stage of projected work (siting, construction, operation, monitoring, closure, and decommissioning).

It is important to note that in a third-party technical review, it is neither practical nor feasible to review each and every detailed technical assumption used by the Joint Waste Owners (JWO) in setting their requirements for the development of the conceptual designs. However, it is possible to review the high-level assumptions and technical bases, which provide the underpinning for the overall conclusions. These "key assumptions" relate primarily to:

- the nature of the technology employed (Technical Risk);
- the timetable or schedule for various actions (Schedule Risk);
- the type and amount of used fuel to be considered (Economic Risk); and
- the likelihood of changes to these key considerations (Societal or Political Risk related to changes in the overall "environment").

These parameters provide a comprehensive basis for concluding that the conceptual designs and transportation plans are "flexible enough" to adapt to future changes. If the conceptual designs and transportation plans do not have this inherent technical flexibility, there is a significant risk of subsequent schedule, economic, societal or political implications.

In summary the key findings and observations are as follows:

- All of the conceptual designs are credible and technically feasible.

- Design details are consistent with the "conceptual" nature of the work. There is no reason to suspect that an appropriate "final design" could not be developed for an approach selected from the designs reviewed.

- All of the conceptual designs have the flexibility to provide increased used fuel storage capacity in the future, by building either incremental additions or completely new facilities. The current conceptual designs are conservatively sized, but limited to the CANDU fuel inventory from "existing" reactors.

- The technical specifications set by the JWO are limited to "existing reactors" and CANDU fuel. This is certainly a reasonable basis for this phase of the conceptual design work, since the vast majority of the current inventory in Canada falls into this category. However, Canada's program for management of used nuclear fuel is expected to continue for many hundreds of years. As such, there may be other fuel types and even potentially other reactor types in the future. It would be prudent for the NWMO to ensure that the recommended conceptual design is flexible enough "in principle" to adapt to future requirements.

- Many international jurisdictions now include an assessment of potential terrorist threats [e.g. aircraft crash] for nuclear facilities – including used fuel facilities. In the conceptual designs which were reviewed, there is limited detail concerning the security arrangements. However, this is to be expected due to the nature of nuclear security issues since these requirements are usually addressed in separate procedures and documentation. Based on the documents reviewed, there is no reason to expect that these issues could not be adequately addressed in any of the designs.

6.0 Results of Assessment:

The results of the review are set out in the following section in accordance with the criteria established by the NWMO when the work was commissioned.

6.1 Specific Findings in Relation to NWMO Criteria

6.1.1. Document the process and assumptions used by the Joint Waste Owners to develop the conceptual designs for each method.

Key Findings:

- The JWO has provided technical specifications (or Request for Proposal (RFP) detailed requirements) for all of the conceptual engineering designs.

- The design process included design reviews and/or revisions to draft documentation to ensure that it met the clients' requirements.

- All of the design concepts and logistics for the transportation program are based upon existing design experience and proven technologies. While regulations and licensing requirements may change in the future, it is anticipated that the current "conceptual" designs could readily be adapted to meet any evolutionary developments.

- Some details of the design process are included in the documentation. For example, the DGR conceptual design is particularly clear and thorough in this regard, but all of the designs include some of this information consistent with what would be expected at the conceptual design stage. Site-specific details would be dependent on the ultimate site selection in any case.

- All of the conceptual designs are limited to commercial CANDU fuel from "existing" reactors. There is reference to "smaller quantities of non-standard and experimental fuel from AECL" but no indication as to how this will be handled. However, there is no reason to expect that these other AECL experimental fuel sizes and types could not be suitably packaged and ultimately accommodated in the various conceptual design concepts.

- The timetable for shipments from the "existing" reactor sites to the CES (assumed in-service ~2023) or to the DGR (assumed in-service ~2035) is not unreasonable, given the currently existing space available for on-site storage. However, future political (or environmental and regulatory) imperatives could result in a desire for either a faster, or a slower schedule. The potential impact of alternative schedule considerations does not appear to have been addressed in the transportation scenarios which were requested by the JWO.

(Further information on the "Detailed Review of Design Process and Assumptions" is included in Appendix 2.)

6.1.2. Comment on how each method has been described to account for possible future changes in the volume of fuel used and other key related assumptions.

Key Findings

- All of the conceptual designs have the "flexibility" to provide increased used fuel storage capacity in the future, by building either incremental additions or completely new facilities. The current conceptual designs are conservatively sized, but limited to the CANDU fuel inventory from "existing" reactors.

- The technical specifications set by the JWO are limited to "existing" reactors and CANDU fuel based on the standard 37-element design. This is certainly a reasonable basis for this phase of the conceptual design work, since the vast majority of the current inventory in Canada falls into this category. However, Canada's program for management of used nuclear fuel is expected to continue for many hundreds of years. As such, there may be other fuel types (e.g. SEU, MOX, DUPIC, etc.) and even potentially other reactor types (e.g. PWR) in the future which have different used fuel characteristics. It would be prudent for the NWMO to ensure that the recommended conceptual design is "in principle" flexible enough to adapt to future requirements.

- The timetable for shipments from the "existing" reactor sites to the CES (assumed in-service ~2023) or to the DGR (assumed in-service ~2035) is not unreasonable, given the currently existing space available for on-site storage. However, future political (or environmental and regulatory) imperatives could result in a desire for either a faster, or a slower schedule. The potential impact of alternative schedule considerations does not appear to have been addressed in the transportation scenarios which were requested by the JWO.

- For all of the transportation scenarios specified by the JWO, the CES and DGR facilities are assumed to be in the province of Ontario. This is not surprising, since it places these facilities near the vast majority of the "existing" used fuel. Moreover, the NWMO should bear in mind that for purposes of preparing estimates for the various approaches a "standardized" site has to be assumed. Hence the designs are based on particular site characteristics representative of an assumed location for the storage or disposal of the used fuel.

  However, recognizing the timeframe for the NWMO's program (hundreds of years) and considering other economic / societal / political factors, other CES or DGR locations are potentially feasible (e.g. northern Saskatchewan) and may become attractive in the future. In addition, over this timeframe other "new" reactor locations (e.g. Alberta tar sands) are also possible. Nevertheless, the current review provides a solid basis for evaluating various transportation options.

6.1.3. Comment on the extent to which the conceptual designs adequately describe the technical methods that the NWMO must study as outlined in Section 12 of the NFWA.

STUDY BY WASTE MANAGEMENT ORGANIZATION

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

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

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

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

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

(*b*) Storage at nuclear reactor sites; and

(*c*) Centralized storage, either above or below ground.

(3) The study must include a detailed technical description of each proposed approach and must specify an economic region for its implementation.

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

(5) Each proposed approach must include a description of the nuclear fuel waste management services to be offered by the waste management organization under section 7.

(6) Each proposed approach must include an implementation plan setting out, as a minimum,

(*a*) A description of activities;

(*b*) A timetable for carrying out the approach;

(*c*) The means that the waste management organization plans to use to avoid or minimize significant socio-economic effects on a community's way of life or on its social, cultural or economic aspirations; and

(*d*) A program for public consultation.

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

Key Findings

- The conceptual designs adequately cover the complete range of technical methods of used fuel management, which are to be studied by the NWMO, as specified in Section 12 of the NFWA.

- Section 12 (2) (a) of the NFWA notes that the DGR must take into account "the views of the environmental assessment panel set out in the *Report of the Nuclear Fuel Waste Management and Disposal Environmental Assessment Panel* dated February 1998." No explicit reference was found regarding how the design had taken these views into account; however, it appears to be implicit in the JWO design specifications [Ref 7]. It may be prudent for the NWMO to prepare a document, which specifically addresses this requirement.

- The technical specifications set by the JWO are limited to "existing" reactors and CANDU fuel based on the standard 37-element design. This is certainly a reasonable basis for this phase of the conceptual design work, since the vast majority of the current inventory in Canada falls into this category. However, Canada's program for management of used nuclear fuel is expected to continue for many hundreds of years. As such, there may be other fuel types (e.g. SEU, MOX, DUPIC, etc.) and even potentially other reactor types (e.g. PWR) in the future which have different used fuel characteristics. It would be prudent for the NWMO to ensure that the recommended conceptual design is flexible enough "in principle" to adapt to future requirements.

- At the present time, the conceptual designs do not include an "economic region" for implementation, as required in Section 12 (3) of the NFWA. (However, the "economic region" for the reactor extended storage concepts is obvious.) In the case of the DGR or CES option, it would appear that the appropriate economic region anticipated by the JWO would be Ontario, since most of the used fuel is located in this region.

- It is anticipated that the implementation plans [referenced in Section 12 (6) of the Act] and the comparisons of benefits, risks and costs [referenced in Section 12 (4) of the Act] for each approach will be part of subsequent work by the NWMO, since this information was not part of the technical documentation which was reviewed.

6.1.4. Comment on the extent to which the conceptual designs for each method have taken into account "natural and other events that have a reasonable probability of occurring" as described in Section 13 of the NFWA.

13. (1) the study must set out, with respect to each proposed approach, a formula to calculate the annual amount required to finance the management of nuclear fuel waste. The report must explain the assumptions behind each term of the formula. The formula must include the following terms:

(*a*) the estimated total cost of management of nuclear fuel waste, which must take into account natural or other events that have a reasonable probability of occurring;
(*b*) The estimated rate of return on the trust funds maintained under subsection 9(1);
(*c*) The life expectancy of the nuclear reactors of each nuclear energy corporation and of Atomic Energy of Canada Limited; and
(*d*) The estimated amounts to be received from owners of nuclear fuel waste, other than nuclear energy corporations and Atomic Energy of Canada Limited, in return for services of management of nuclear fuel waste.

(2) The study must set out, with respect to each proposed approach, the respective percentage of the estimated total cost of management of nuclear fuel waste that is to be paid by each nuclear energy corporation and Atomic Energy of Canada Limited, and an explanation of how those respective percentages were determined.

(3) The study must set out the form and amount of any financial guarantees for the management of nuclear fuel waste that have been provided by the nuclear energy corporations and Atomic Energy of Canada Limited under the *Nuclear Safety and Control Act*.

Key Findings

- As required in Section 13 (1) (a) of the NFWA, the normal operation of the facilities and the details of potential "design basis" wind loads and seismic events are included in the design specifications for the above-ground facilities.

- The CES conceptual design notes specifically that additional seismic assessments should be done for below-ground facilities to confirm that there is no risk of casks (which are stacked two-high in the conceptual design) toppling over [Ref 5: Chapter 10 on Unresolved Design Issues].

- Section 13 (1) (c) of the NFWA requires an estimate of the "life expectancy" of the nuclear reactors. While this information was not described in detail in the technical specifications, it is anticipated that the NWMO has access to additional documentation which provides a justification for these assumptions (including potential "life extension" plans for the reactors).

- Many international jurisdictions now include an assessment of potential terrorist threats [e.g. aircraft crash] for nuclear facilities – including used fuel facilities. While this may have been included in other documentation [Ref 20], there is no evidence of this type of security assessment in the conceptual designs which were reviewed. [Such assessments tend to favour consolidation of used fuel in below-ground facilities or repositories.]

- Since Section 13 of the NFWA is aimed at financial, economic and liability issues, it is important to view the reference to "natural or other abnormal events" in this context, as they could have some impact on the overall cost of the facilities or transportation scenarios. Some natural events have been included in the design basis of the concepts reviewed but the documents specifically note that in certain cases further studies need to be carried out. Also, the cost impact of the "abnormal" event of alternative fuels is not addressed since the designs do not specifically consider this possibility. In addition, abnormal institutional events (or ethical considerations) such as a potential mandate to take back used fuel from CANDU owners overseas, politically mandated moratorium on nuclear power, or alternatively an accelerated program are not considered. Any of these would have a significant economic impact on the designs as presented. Note that none of these options are currently Canadian government policy but it is plausible that given the time frames involved a future government could mandate such approaches. In consultation with the JWO and the relevant regulatory authorities, the NWMO may wish to give further consideration to the appropriate range of "design basis" and "abnormal event" scenarios.

6.1.5. Map the document trail that supports the conceptual designs, assess the documentation and comment on the quality and completeness of the documentation.

Key Findings

- Initial assumptions are well defined by JWO, based upon previous work, internal review, and/or international approaches.

- JWO sets technical specifications (or RFP detailed requirements) for execution of the conceptual engineering designs.

- Process included design review and revisions to draft documentation to ensure that it met the clients' requirements. Documents indicate that they have been checked and reviewed.

- Design documentation has been prepared in sufficient detail that it represents full conceptual design for each option. Also the documentation has been prepared and organized consistent with accepted engineering practice.

- A document map is included in Appendix 3.

6.1.6. Document how accepted engineering standards were followed in the development of the various conceptual designs.

Key Findings

- The engineering and design organizations involved in the conceptual designs are internationally recognized experts and familiar with engineering standards and code requirements.
- Relevant engineering standards are referenced in the conceptual design documents, including CSA, National Building Code and other internationally recognized design approaches [e.g. Ref 5: Chapter 11 on Codes and Standards]
- Design documentation has been prepared in sufficient detail that it represents full conceptual design for each option. Also the documentation has been prepared and organized consistent with accepted engineering practice.
- The documentation is of such quality and detail that it is expected that the final design of any of the options would ultimately be licensed by the Canadian Regulatory authority and meet their requirements.

6.1.7. Deliver a signed opinion on the processes and standards that were followed in developing the conceptual engineering designs and the extent to which the descriptions of the conceptual designs for each method adequately meet the requirements of the NFWA.

Opinion Elements

- Conceptual engineering designs based upon technical specifications (or RFP detailed requirements) defined by the JWO.
- Process included design review and revisions to draft documentation to ensure that it met the clients' requirements.
- The conceptual designs adequately cover the complete range of technical methods of used fuel management, which are to be studied by the NWMO.
- All of the conceptual designs are credible and technically feasible.
- Design details are consistent with the "conceptual" nature of the work. There is no reason to suspect that an appropriate "final design" could not be developed and licensed for the selected approach.
- All of the conceptual designs have the flexibility to provide increased used fuel storage capacity in the future, by building either incremental additions or completely new facilities. The current conceptual designs are conservatively sized, but limited to the CANDU fuel inventory from "existing" reactors.

6.2 Opinion Letter

ADH Technologies Inc. developed an opinion letter regarding the team's findings from the review. This letter is attached.

ADH
Technologies Inc.
"Bringing Innovation to Market"

Ms. Elizabeth Dowdswell
President
Nuclear Waste Management Organization
49 Jackes Avenue, 1st floor
Toronto, Ontario, M4T 1E2

June 4, 2004

Dear Ms Dowdswell,

ADH Technologies Inc. has been engaged by the NWMO to review a set of conceptual design documentation representing three nuclear spent fuel management options and associated transportation documentation where applicable. We have undertaken this review and set out our specific and overall conclusions in our report that has been submitted to you separately.

In our opinion the designs are sufficiently well developed and documented to represent what is normally expected of conceptual design level documentation. The documentatic is well developed and has been checked and reviewed in a manner consistent with established engineering practice.

As such we would conclude that the conceptual design documentation is suitable for the purpose of assessment of options and directional decision making. We would also expect that any of the three approaches reviewed could be developed into a detailed design that would meet the overall NWMO program requirements if consistent and appropriate engineering practices are employed.

We appreciated the opportunity to work with the NWMO in reviewing these conceptual designs.

Yours sincerely,

A. D. Hink. P. Eng.
President

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7.0 Overall Assessment

The reviewers have come to the following overall conclusion concerning the conceptual designs that were reviewed;

- All of the conceptual designs are credible and technically feasible.

- Design details are consistent with the "conceptual" nature of the work. There is no reason to suspect that an appropriate "final design" could not be developed for an approach selected from the designs reviewed.

- All of the conceptual designs have the flexibility to provide increased used fuel storage capacity in the future, by building either incremental additions or completely new facilities. The current conceptual designs are conservatively sized, but limited to the CANDU fuel inventory from "existing" reactors.

- The technical specifications set by the JWO are limited to "existing" reactors and CANDU fuel. This is certainly a reasonable basis for this phase of the conceptual design work, since the vast majority of the current inventory in Canada falls into this category. However, Canada's program for management of used nuclear fuel is expected to continue for many hundreds of years. As such, there may be other fuel types and even potentially other reactor types in the future. It would be prudent for the NWMO to ensure that the recommended conceptual design is "in principle" flexible enough to adapt to such future requirements.

The conceptual designs are assessed to be suitable for the intended purpose which is to assess the options presented and arrive at a recommended approach. The conceptual designs are well developed and documented and prepared in a manner consistent with established engineering practice.

Accordingly it is reasonable to expect that any of the options reviewed could be developed into a full detailed design that would meet the requirements of the NWMO program. It should be noted however, that should there be requirement to accommodate non-standard fuels the designs would have to be adapted to address such a need. It is reasonable to expect that this could be done within the overall design concepts presented although their would be an impact the overall system design and program cost. The precise impact will need to be assessed if the non-standard fuel scenario was to be developed.

8.0 Recommendations

As noted above, the conceptual designs are well developed and meet the objectives as stated in the original requirements. While the conceptual designs can be adapted to accommodate alternate fuel designs, they do not address how this will be done and what the impact will be on the design and facility cost.

It is the reviewer's belief that there is a significant probability that there will be a need to adapt the used fuel management system design to accommodate multiple fuel types. This will have an impact on the design configuration and the facility costs that should be further investigated by the NWMO.

In addition, further considerations of potential schedule changes and/or alternative site and facility locations, would provide the NWMO with a better picture of the overall technical "flexibility" of the conceptual designs and their ability to adapt to changing requirements over the long term.

Accordingly the following is recommended:

1. The NWMO should organize a third-party study to address the scenario of multiple fuel types being stored for each of the options. Fuel types to be considered should include MOX, DUPIC, PWR, SEU, and reprocessing products. The study should evaluate the overall impact on the program including facility design, cost, and program schedule. This study should be completed in sufficient time to enable the NWMO to include the results in its recommendation to the government.
2. The results of this study would allow the NWMO to demonstrate that the conceptual designs reviewed address the requirements of Article 13 of the NFWA where it is mandated that consideration be given to "natural and abnormal" events that have reasonable probability of occurring. The NWMO should then formulate a formal opinion on this requirement based on this independent review.
3. The NWMO should address the situation of an accelerated or decelerated program that could result from a future political mandate. The program time frames are such that this scenario is possible as circumstances change in the future.

REFERENCES

Documents Reviewed

1. "*Conceptual Designs for Reactor-site Extended Storage Facility Alternatives for Used Nuclear Fuel. Alternatives for Pickering, Bruce and Darlington Reactor Sites.*"
   CTECH Report No: 1105/MD18084/REP/12 – April 2003

2. "*Conceptual Designs for Reactor-site Extended Storage Facility Alternatives for Used Nuclear Fuel. Alternatives for New Brunswick Power's Point Lepreau Reactor Site.*"
   CTECH Report No: 1105/MD18084/REP/13 – April 2003

3. "*Conceptual Designs for Reactor-site Extended Storage Facility Alternatives for Used Nuclear Fuel. Alternatives for Hydro-Québec's Gentilly Reactor Site.*"
   CTECH Report No: 1105/MD18084/REP/14 – April 2003

4. "*Conceptual Designs for Reactor-site Extended Storage Facility Alternatives for Used Nuclear Fuel. Alternatives for Atomic Energy of Canada Limited's Chalk River and Whiteshell Laboratory Sites.*"
   CTECH Report No: 1105/MD18084/REP/15 – April 2003

5. "*Conceptual Designs for Four Centralized Extended Storage Facility Alternatives for Used Nuclear Fuel.*"
   CTECH Report No: 1105/MD18084/REP/08 – April 2003

6. "*Conceptual Designs for a Deep Geologic Repository for Used Nuclear Fuel.*"
   CTECH Report No: 1106/MD18085/REP/01 – December 2002

7. "*Technical Specification for Updating the Conceptual Design and Cost Estimate for a Deep Geologic Repository for Used Nuclear Fuel*"
   OPG Document No: 06819-UFM-03789-0001 R00, Rev 0 – March 2001

8. "*Study of ESF Options for OPG's, NBP's, HQ's and AECL's Used Nuclear Fuel. Attachment 3: Scope of Work* and *Attachment 4: CES System Requirements*"
   OPG Document No: 06819-01110 T10 – July 2001

9. "*Design Basis for Centralized Extended Storage Alternatives for Used Nuclear Fuel.*"
   CTECH Report No: 1105/MD18084/REP/04 – May 2002

10. "*Study of ESF Options for OPG's, NBP's, HQ's and AECL's Used Nuclear Fuel. Attachment 5: RES System Requirements*"
OPG Document No: 06819-01110 T10 – July 2001

11. "*Conceptual Designs for Transportation of Used Fuel to a Centralised Facility*"
Cogema Logistics Report No: 500276-B-005 rev. 00 – May 2003

12. "*Logistics of Transportation of Used Fuel to a Centralised Facility*"
Cogema Logistics Report No: 500276-B-009 rev. 00 – September 2003

13. "*Used Fuel Transportation Study. Attachment 3: Scope of Work* and *Attachment 4: System Requirements*"
OPG Document No: 06819(UF)-03789 – July 2002

14. "*Cost Estimates for Four Centralized Storage Facility Alternatives for Used Nuclear Fuel.*"
CTECH Report No: 1105/MD18084/REP/11 – (May 2003 version only)

15. "*Cost Estimates for Reactor-site Extended Storage Facility Alternatives for Used Nuclear Fuel. Alternatives for Pickering, Bruce and Darlington Reactor Sites.*"
CTECH Report No: 1105/MD18084/REP/16 – December 2003

16. "*Cost Estimates for Reactor-site Extended Storage Facility Alternatives for Used Nuclear Fuel. Alternatives for New Brunswick Power's Point Lepreau Reactor Site.*"
CTECH Report No: 1105/MD18084/REP/17 – December 2003

17. "*Cost Estimates for Reactor-site Extended Storage Facility Alternatives for Used Nuclear Fuel. Alternatives for Hydro-Quebec's Gentilly Reactor Site.*"
CTECH Report No: 1105/MD18084/REP/18 – December 2003

18. "*Cost Estimates for Reactor-site Extended Storage Facility Alternatives for Used Nuclear Fuel. Alternatives for AECL's Chalk River and Whiteshell Reactor Sites.*"
CTECH Report No: 1105/MD18084/REP/19 – December 2003

19. "*Cost Estimate for a Deep Geologic Repository for Used Nuclear Fuel.*"
CTECH Report No: 1106/MD18085/REP/02 – September 2003

20. *"Letter From Frank King to Elizabeth Dowdswell"* File No. 06819 (UF)-08104.12 NWMO T10, May 3,2004

APPENDIX 1

Resumes of Review Team Members

Mr. A. D. Hink, P. Eng. & President, ADH Technologies Inc. – Team Leader

Mr. Hink is a Professional Engineer with many years experience managing major nuclear projects. His particular areas of expertise include engineering and project management of nuclear projects. He is highly respected as a developer of major nuclear projects from the initial marketing to proposal preparation, presentation to the clients, and through engineering to project completion. He has undertaken this responsibility for a number of nuclear facilities in the past. These projects have been successfully implemented. He has led the strategic planning function at the executive level for AECL and he was responsible for executive oversight of AECL's waste management programs in this role.

Mr. Pierre Galiungi, P.Eng,

Mr. Galiungi is a Professional Engineer. He is a Fellow of the prestigious Institution of Civil Engineers, (FICE), and a Fellow of the Institution of Engineers of Australia (FIE) and carries the designation of European Engineer (Eur Ing). He has many years of hands-on experience as a construction manager and project manager with a true grasp of how projects are developed and executed. His experience extends to work on five continents and includes nuclear facilities, hydro- generation, heavy industrial and commercial projects and work in remote areas of the Canadian Arctic. Mr. Galiungi has particularly strong skills at cost management and cost control. These skills, combined with his experiences make Mr. Galiungi particularly well suited to reviewing projects with a view to judging their completeness and that proper consideration is given to risk elements and application of appropriate standards.

Mr. Robert D. Gadsby, M. Sc. (Nuclear Physics)

Mr. Robert Gadsby has over 30 years of experience in the Canadian nuclear industry and has served in a wide variety of senior management positions with Atomic Energy of Canada Limited (AECL).

Most recently, Mr. Gadsby was General Manager, Waste Management and Decommissioning – with responsibility for directing the development of AECL's Canadian and international waste management service business (including AECL's cooperative programs with the IAEA and other international waste management organizations).

Mr. Gadsby has extensive experience in reviewing client needs, evaluating and assessing technical options, and providing project management oversight of nuclear waste management projects. In addition, he has expertise in nuclear fuel cycle options and is familiar with the full spectrum of reactor fuel types (fuel handling, storage, transportation, security, waste management and disposal) which could potentially be used in Canada's nuclear program (including Natural Uranium, SEU, DUPIC, MOX and even PWR fuel options).

Mr. Gadsby has also been an "expert witness" regarding the Douglas Point safety and licensing at the Ontario Select Committee hearings into nuclear power.

APPENDIX 2

Detailed Review of Design Process and Assumptions:

- **DGR**
  - DGR Technical Specifications provided [Ref 7]
    - Design concept limited to commercial CANDU fuel and "smaller quantities of non-standard and experimental fuel from AECL."
    - "Reference" fuel conditions after 30 years of storage [vs. 10 years of storage in previous AECL design concept]
    - "Container Design" parameters specified and linked to "current" CANDU reactor fuel
  - Revisions to AECL design concept described with solid technical details
  - Generic granite site conditions, but capable of adaptation for site specifics
  - NO "formal" optimization of system, component performance, or cost
  - Thorough technical review of fuel transfer, handling, and emplacement
  - Detailed description of "Design Process" provided
  - Capacity of DGR set at 3,600,000 bundles (conservative for "existing" reactors)
  - Excavation concept based upon proven techniques
  - UFPP designed to Canadian standards for concrete containment structures of CANDU generating stations (including seismic loading), which is appropriate considering the used fuel inventory "in process"
  - Conceptual design includes review of the possibility of "retrieval" of emplaced UFC
  - Concept includes plans for siting, construction, operation, extended monitoring, decommissioning, and closure phases

- **CES**
  - CES general Technical Specifications provided [Ref 8]
    - Design concepts limited to "dry storage" options with "passive cooling"
    - Design based on commercial CANDU fuel ("existing" reactors)
    - "Reference" fuel conditions after 20 years of storage out-reactor
    - CES facility to permit safe retrieval of used fuel, during its service life
    - Capability to handle 120,000 bundles/year
  - Additional "Design Basis" information [Ref 9]
  - Capacity of CES set at 3,600,000 bundles (conservative for "existing" reactors)

- Concept based upon a "greenfield" site
- Concept uses of a "rolling program" of demolition and renewal to provide for an "indefinite" service life (evergreen)
- Design approach based upon "existing" technologies (and requirements)
  - 1 in 100 year wind load
  - "Design basis earthquake", etc.

- **Casks and Vaults in Storage Buildings** (CVSB)

  - "Passive" cooling (natural convection) within storage buildings
  - Remote fuel handling capability provided in shielded cell complex in the Processing Building (which has active ventilation and filters)
  - Retrieval simplified since there is no stacking of casks

- **Surface Modular Vault** (SMV)

  - Totally "passive" cooling (natural convection) across storage vault tube arrays
  - Fuel is transferred from reactor sites in Irradiated Fuel Transportation Casks (IFTCs) or basket transportation casks.
  - Remote fuel module and basket handling capability provided in shielded cell complex in the Processing Building (which has active ventilation and filters)
  - Retrieval possible throughout service life
  - Double containment of used fuel

- **Casks and Vaults in Shallow Trenches** (CVST)

  - "Passive" cooling (natural convection) within storage buildings
  - Remote fuel handling capability provided in shielded cell complex in the Processing Building (which has active ventilation and filters)
  - Casks are stacked two high – slightly more difficult retrieval
  - Earthen cover and concrete chambers provide improved intrusion resistance

- **Casks in Rock Caverns** (CRC)

  - Based on "forced ventilation" instead of "passive" cooling [contrary to the technical specification, but understandable]
  - Casks stored in caverns in "competent" bedrock
  - Casks are stacked two high – slightly more difficult retrieval
  - Caverns in bedrock structures are designed to provide maximum protection and containment

- Increased storage capacity can be created when required, via the rolling-program of construction
- Concept includes plans for siting, construction, operation, extended monitoring, facility repeats, and repackaging activities
- Some "Unresolved Design Issues" are identified
  - Potential interface issues related to the basket transportation flask
  - Further assessment needed (for heat dissipation, shielding, etc.) of CRC basket storage cask
  - Potential seismic issues related to stacking of casks in the below-grade options
  - Impact of cask stacking on heat rejection
  - Need for detailed thermal analysis to validate ventilation arrangements
- NO specific mention of safety performance for "abnormal events" (other than earthquake)

- **RES**

  - RES Technical Specifications provided [Ref 10]
    - Design concepts limited to fuel from "current" Canadian nuclear program
    - "Non-standard" fuel (e.g. AECL research) is NOT within the scope of the RES facility options study at this time
    - RES facility functional requirements:
      - safe containment and retrieval
      - mechanical protection
      - cooling
      - shielding
      - monitoring capability during operation and subsequently
    - "Reference" fuel conditions after 10 years of storage out-reactor
    - Containment structures to have long-term resistance to "extreme" site conditions
    - Containment structures capable of replacement consistent with "extended storage"
    - Safety performance to include normal operations and "abnormal" events
  - All RES concepts include the "currently existing" facilities as part of the "base case"

  - **Bruce, Pickering and Darlington**

    - Design concept reviews

            - Casks in Storage Buildings (CSB)
            - Surface Modular Vault (SMV)
            - Casks in Shallow Trenches (CST)
        - Site specific application of alternatives

    - **Point Lepreau**

        - Design concept reviews
            - Silos
            - Surface Modular Vault (SMV)
            - Vaults in Shallow Trenches (VST)
        - Site specific application of alternatives

    - **Gentilly**

        - Design concept reviews
            - Vault
            - Surface Modular Vault (SMV)
            - Vaults in Shallow Trenches (VST)
        - Site specific application of alternatives

    - **Chalk River and Whiteshell**

        - Design concept reviews
            - Silos
            - Silos in Storage Buildings (SSB)
            - Silos in Shallow Trenches (SST)
        - Site specific application of alternatives

    - All concepts include plans for siting, construction, operation, extended monitoring, facility repeats, and repackaging activities
    - For any of the above RES concepts, additional storage capacity can be created when required, by building new silos, storage buildings, and facilities
    - NO specific mention of safety performance for "abnormal events" (other than earthquake)

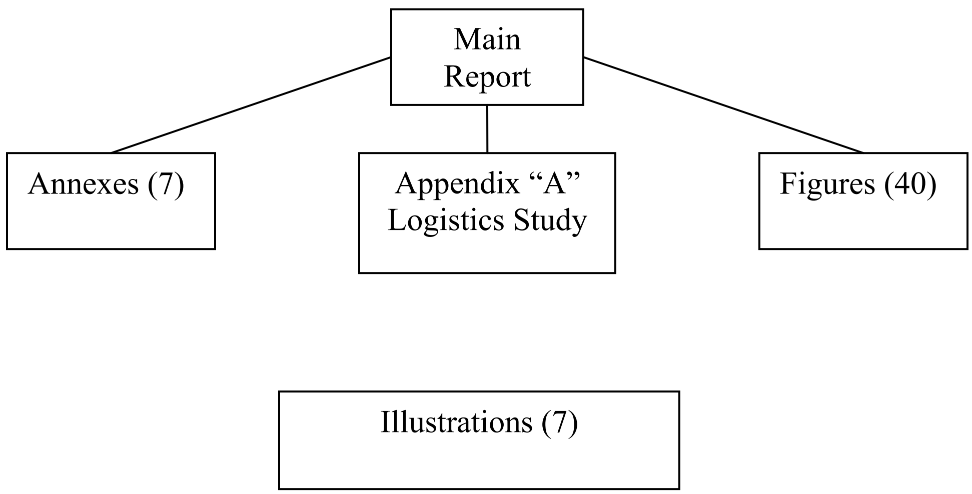
- **Used Fuel Transportation System (UFTS)**

    - Phase 1 "Conceptual Design Report" [Ref 11]; Phase 2 "Logistics Report" [Ref 12]; and Phase 3 "Capital and Operating Cost Estimates" reviewed

- UFTS Technical Specifications provided [Ref 13]
  - Functional requirements:
    - Interface with current storage facilities
    - Load fuel into suitable transportation package
    - Transport to centralized long-term management facility
    - Provide containment, protection, shielding, heat dissipation during transport
    - Interface with receiving facility
    - Provide facilities, handling, casks, vehicles, security, safeguards, etc.
  - Design concept limited to commercial CANDU fuel from "existing" reactors [non-CANDU fuel outside scope of this study]
  - "Reference" fuel conditions after 10 years of storage out-reactor
  - Shipping rate of 120,000 bundles/year over a 30-year period
- Three UFTS options considered
  - "All Road" mode
  - "Mostly Rail" mode
  - "Mostly Water" mode
- Concept based upon transportation to a CES (in-service ~2023) or DGR (in-service ~2035) facility in Ontario portion of the Canadian Shield
- UFTS based upon one existing and one new cask:
  - OPG's Dry Storage Container Transportation Package (DSCTP)
  - Irradiated Fuel Transportation Cask for Baskets or Modules (IFTC/BM)
- Concept includes transportation from the currently "existing" seven reactor sites … and takes into account storage in the five "existing" methods (baskets in silos, baskets in CANSTOR, trays in wet bays, modules in wet bays, modules in dry storage containers)
- Concept is based upon currently existing technology and experience (including international experience)
- Thorough step-by-step review of the logistics for transportation
- Concept includes plans for design, construction, commissioning, operation, maintenance and decommissioning of the loading facilities at the various nuclear facilities.
- UFTS concept includes studies of feasible routes, transportation system development, safety assessments, development of suitable transportation package designs, detailed transporter design, transfer facilities and infrastructure, operation, environmental management, decommissioning, etc.
- UFTS also includes concepts for "emergency response" and "real time tracking" plans

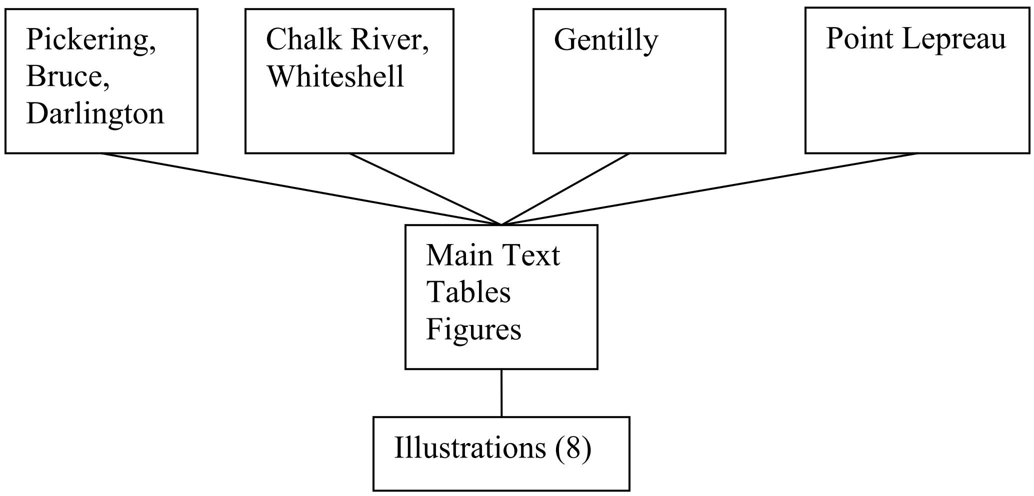
APPENDIX 3

Conceptual Design Map – Deep Geologic Disposal (DGR)



APPENDIX 4

Conceptual Design Map – Reactor Site Extended Storage (RES)



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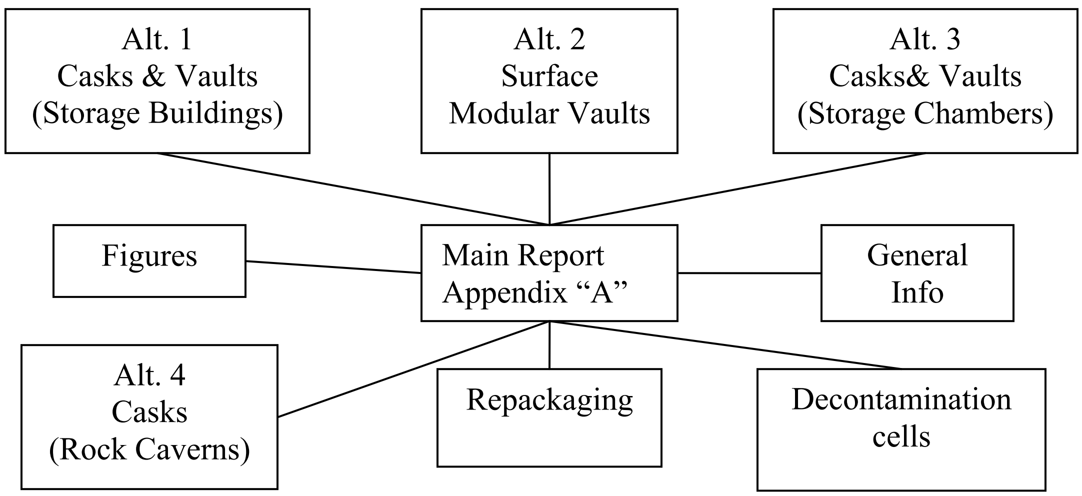
APPENDIX 5

Conceptual Design Map – Centralized Extended Storage (CES)



APPENDIX 6

Conceptual Design Map – Transportation of Used Fuel