Mined Geologic Disposal System (MGDS)
Annotated Outline Skeleton Text
for the Preparation of a License Application

May 28, 1993

Volume I of II

Revision 2

U.S. Department of Energy
Office of Civilian Radioactive Waste Management
Washington, DC

Prepared by:

TRW Environmental Safety Systems Inc.
2650 Park Tower Drive
Suite 800
Vienna, Virginia 22180

Under Contract Number DE-AC01-91RW00134

CRWMS M&O Document Number
TSO.920219.0187

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Section 5.2 Assessment of Compliance with 10 CFR Part 60

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INN 5.2-004	How to evacuate water from Waste Packages
INN 5.2-005	Retrievability design options
INN 5.2-006	EBS design options allowing for a performance confirmation program
INN 5.2-007	A model describing the potential pre-conditioning of the glass surface by hot humid air.
INN 5.2-008	Gap inventory of radionuclides in spent fuel

5.2 ASSESSMENT OF COMPLIANCE WITH 10 CFR PART 60

5.2.1 Assessment of Compliance for Particular Barriers

5.2.1.1 Waste Package Design Requirements

The basis for the development of the waste package design involves many elements. These include the regulatory requirements, design goals, environmental scenarios, interfaces with other engineered features and the natural barriers, waste form properties, containment barrier properties, and programmatic inputs. The regulatory requirements include those taken from 10 CFR Part 20, Part 60, and, by reference, 40 CFR Part 191, and cover both pre-closure and post-closure periods. [40 CFR 191 has been remanded. The repromulgation will include input from the National Academy of Sciences as mandated by the Comprehensive National Energy Policy Act of 1992.] The applicable sections of the regulations are given below:

REGULATIONS	APPLICABLE SECTION	
	Pre-closure	Post-closure
10 CFR Part 20	20.101-20.108	N/A
10 CFR Part 60	60.135 (b),(c), 60.131 (b)(7), 60.137 and Subpart F, and 60.111	60.113 and 60.135(a) 60.112, and 60.21(c)
40 CFR Part 191	191 Subpart A	191.13

5.2.1.1.1 Pre-Closure Design Requirements

The pre-closure requirements taken from the above references are detailed below:

1. Handling

   a) The waste package [provides] for safe handling of the waste, at least to the end of the period of retrievability, or until the repository is closed. [This section to be completed using INN 5.2-001]

   b) The waste package [is] capable of sustaining normal handling and packaging operational loads without loss of containment, and design basis accidents either without loss of containment or with a limited release of radionuclides. [This section will be completed using INN 5.2-001]

   c) The waste package [is] capable of sustaining mechanical loads from rock fall. [This section will be completed using INN 5.2-001]

2. Criticality control

   The internal waste distribution in waste emplacement packages [is designed] such that nuclear criticality [is not] possible unless at least two unlikely, independent, and concurrent or sequential changes have occurred in the conditions essential to nuclear criticality safety. The calculated effective multiplication factor k_{eff} [is] sufficiently below unity to show at least a five percent margin after allowance for bias in the method of calculation and the uncertainty in the experiments used to validate the method of calculation (10 CFR 60.131). [INN 5.2-002]

3. Unique identification

A label or other means of identification for each waste emplacement package [is provided]. The identification [does] not impair the integrity of the waste emplacement package and [is] applied in such a way that the information [is] legible at least to the end of the period of retrievability. Each waste emplacement package identification [is] consistent with the waste emplacement package's permanent written records (10 CFR 60.135 (b) (4)). [This section will be completed using INN 5.2-003]

4. Explosive, pyrophoric, and chemically reactive materials

The waste emplacement package [does not] consist of explosive or pyrophoric materials or chemically reactive materials in an amount that could compromise the ability of the underground facility to contribute to waste isolation or the ability of the geologic repository to satisfy the performance objectives (10 CFR 60.135(b)(1)). [Refer to the Waste Acceptance Specifications.]

5. Free liquids

The waste emplacement package [does not] contain free liquids in an amount that could compromise the ability of the waste packages to achieve the performance objectives relating to containment of high-level waste (because of chemical interaction or formation of pressurized vapor) or result in spillage and spread of contamination in the event of waste package perforation during the period through permanent closure (10 CFR 60.135(b) (2)). [This section will be completed using INN 5.2-004.]

6. Retrievability

The repository (and therefore the waste packages) [is] designed to preserve the option of waste retrieval throughout the period during which wastes are being emplaced or until the repository is closed (10 CFR 60.111(b)(1)). [This section will be completed using INN 5.2-005.]

7. Performance confirmation

The repository (and therefore the engineered barrier system) [is] designed to permit implementation of a performance confirmation program (10 CFR 60.137 and Subpart F).

5.2.1.1.2 Post-Closure Design Requirements

The primary post-closure regulatory requirements are from 10 CFR Part 60, particularly the engineered barrier performance objectives in 60.113. This section mandates two specific performance objectives for the waste package and EBS after the closure period of the repository and divides the post-closure period into two time periods, conventionally referred to as the "containment" and "controlled-release" periods. [This section will be completed using INN 5.2-006.]

1. Containment

Containment, "within the waste packages will be substantially complete for a period to be determined by the Commission...not less than 300 nor more than 1,000 years after permanent closure of the geologic repository." Recently, the NRC has recognized, in a 1990 Staff Position, SP-60-001, entitled, "Containment Period for High-Level Waste Packages," that the DOE can take credit for containment beyond the 1,000-year period.

2. Controlled Release

The controlled-release requirement applies to the EBS, which includes the waste packages. The release from the EBS, "following the containment period shall not exceed one part in 100,000 per year of the inventory of that radionuclide calculated to be present at 1,000 years following permanent closure."

The overall system performance objective in 10 CFR 60.112 relates to limits on the releases of radioactive materials to the accessible environment following permanent closure as established by the EPA. Other requirements from 10 CFR Part 60 also need to be addressed. These include 60.21(c)(1)(ii)(D) on an analysis . . . includ[ing] a comparative evaluation of alternatives to the major design features . . . that would provide longer radionuclide containment and isolation, and 60.137 and Subpart F that present requirements for performance confirmation.

[The development of models for the degradation of the container material and breach of the container follow the framework of the model hierarchy discussed above. The goal is to develop a model that incorporates mechanistic understanding of the degradation and breach processes, based on experimental observations. The models are supported by a parallel container materials testing effort. The result is a mathematical expression that describes the process for each container material. The prediction of degradation is deterministic and includes the variability of the process. However, the breach of the container barrier(s) is expressed probabilistically to provide the starting points for the initiation of degradation of the inner container and the subsequent initiation of the degradation of the waste form and the potential release of radionuclides.]

[The outer barrier is made from a corrosion-allowance material; the dominant corrosion mode is uniform oxidation/corrosion. (Localized attack, stress corrosion cracking, and mechanical failure are usually not important for this class of materials.) Oxidation can take place during the period when the containers are exposed to hot humid air. The oxidation rate under these atmospheric conditions may be linear (non-protecting) or parabolic (protecting). The goal of the materials

development effort is to select a material for which a protective oxide film develops and remains intact over time. If protecting, the degradation rate decreases with time and the total degradation follows a power-law function, usually a square root dependence, with time. For linear (non-protecting) corrosion, the degradation rate is linear with time.]

[The inner barrier may be one of the corrosion-resistant materials extensively studied by LLNL that has received high rankings as a result of the application of the selection criteria. These materials include Alloy 825, Alloy C-4, and titanium Grade 12. The dominant corrosion mechanisms for these materials are more likely to be localized attack and stress corrosion cracking. (Mechanical failure and uniform oxidation/corrosion are not likely to be important degradation modes for these materials.)]

[Expressions are developed describing the degradation of the container by each of the possible mechanisms. These expressions are combined to obtain the degradation rate. This rate reveals the starting point of degradation of the waste form and the potential release of radionuclides.]

[The HLW canister and the spent fuel cladding also provides a redundant containment barrier. This possibility is clarified by ongoing research on these barrier materials, austenitic stainless steel AISI 304L and Zircaloy. These barriers provide added confidence that the containment requirements will be met.]

5.2.1.2 Waste Form

The basis of the waste forms involves principally the regulatory requirements of 10 CFR 60.135 as shown below:

1. All such radioactive waste [is] in solid form and placed in sealed containers.

2. Particulate waste [is] consolidated (for example by incorporation into an encapsulating matrix) to limit the availability and generation of particulates.

3. All combustible material [is] reduced to a noncombustible form.

4. The waste form [does not] contribute to free liquids in the waste package in an amount that would compromise the ability of the waste package to achieve the performance objectives.

5. The waste form [does not] contain explosive, pyrophoric, or chemically reactive materials in an amount that could compromise the repository's ability to satisfy the performance objectives.

The waste form also meets the following requirements derived from programmatic inputs [Ref. YMP/92-11]:

1. The waste form [is] capable of sustaining normal and packaging operational loads.

2. The waste form remains solid during handling, emplacement, and retrieval impact loads.

3. The canistered waste form [is] capable of sustaining the design basis drop onto a flat, essentially unyielding surface without breaching.

4. The canistered waste form maintains its overall dimensions such that it can be inserted into the disposal container without forcing.

Models have been developed that describe the long-term dissolution behavior of HLW glass over time. [To this, a model must be added that describes the potential pre-conditioning of the glass surface by hot humid air. The models are partially validated through the use of natural analogues of other glasses, e.g., basaltic glasses (INN 5.2-007).]

The modeling of spent fuel is much more complicated and must include the cladding (considered under the container materials section), the gap (between the pellet and the cladding), the fuel grain boundary, and the matrix. The gap and grain boundary radionuclide inventory is considered to be readily available for dissolution when contacted by water. The inventory of radionuclides in the gap and grain boundaries, for low gas-release fuel, is about two percent of the total inventory of those species [INN 5.2-008]. Low, gas-release fuel represents a major fraction of the present inventory. The inventory for higher gas-release fuel is roughly proportional to release.

[The matrix dissolution appears to be congruent, i.e., all elements are dissolved uniformly, for a wide range of fuel types and burnups. The dissolution also appears to be correlated to available surface area. The surface area is a function of the state of oxidation, with greater areas associated with increases in the oxidation state. Oxidation state is a function of time and temperature. If the temperature is sufficiently low, the matrix remains in a low (O/M=2.4) oxidation state with a structure of U_4O_9, , and the surface area does not change much with oxidation. At higher temperature, the oxidation state can increase to U_3O_8 or to UO_3, with a much larger surface area, created by the powdering of the material. Testing is performed to further evaluate the effect of temperature and time on oxidation, surface area, and dissolution. A model is developed that describes the mechanism. The models are partially validated through the use of natural analogues, e.g., of uraninite in natural reactor systems such as Oklo and Cigar Lake.]

5.2.1.3 Underground Facility

Skeleton text has not been developed for this subsection.

5.2.2 Assessment of Compliance with Performance Objectives

[The models utilized to evaluate compliance with performance objectives are placed in the context of an overall model hierarchy. This model hierarchy provides the vehicle for the

WP/EBS PA-determined resolution of containment and gradual release issues. At the base of the hierarchy, and providing the technical basis for the PA calculations, are the submodels which characterize quantitatively the performance parameters or responses of the WP/EBS materials/design in the repository environment. As the model hierarchy proceeds to higher level models, the performance parameter submodels may be simplified, but must remain as defensible as at the deterministic/mechanistic submodel level. The test programs described in the Scientific Investigation Plans (SIPs) appear in the model hierarchy as they relate to performance parameter submodels. The testing and modeling activities that are performed provide the basis for the use and defense of these submodels. In a similar manner, the higher level PA analyses provide feedback for the prioritization of test activities and sensitivity analyses (required for design and performance allocation activities).]

Performance assessments determine whether the candidate designs meet the requirements for "substantially complete containment" (SCC) and "controlled release" as defined in 10 CFR 60.113. The process of performance assessment is an interactive one in that many loops through the process are performed until a design is achieved that meets the requirements.

[The approach to model development follows that given in ASTM C 1174-91 (Reference 1). The process calls for the development of mechanistic understanding of waste package materials alteration. If mechanistic understanding cannot be obtained, then partial understanding, leading to semi-empirical models, will be sought. Lastly, if neither full nor partial mechanistic understanding is possible, then bounding models will be utilized. Whatever final model is developed, verification and validation is performed. Note that total validation in the classic sense is not achievable given the time frame of repository performance; however, partial validation may be possible with the aid of natural analogues, both for the corrosion-allowance waste package materials and the waste forms. Long-term and in-situ testing can also add confidence that the degradation modes are understood.]

Assuming anticipated processes and events, the two post-closure objectives in 10 CFR 60.113 require: (1) substantially complete containment within the waste packages for 300 to 1000 years

after closure (i.e., containment), and (2) following the containment period, control of the release of any radionuclide from the EBS to less than 1 part in 100,000 per year of its 1000-year inventory (i.e., controlled release). (See the definitions under section 5.2.1.1.2 paragraph 1.) The period of controlled release is extended to 10,000 years. Although the containment period "shall not be less than 300 nor more than 1000 years after permanent closure," as per 10 CFR 60.113, 1000 years has been chosen by DOE for design purposes. [The DOE will design the waste packages to provide total containment during the containment period under the full range of anticipated repository conditions, recognizing technological limitations and residual uncertainties. These uncertainties include: the inherent limitations associated with manufacturing, handling, and emplacement operations; the uncertainty in developing a complete understanding of the behavior of the waste package materials; and the uncertainty in predicting the environment of each waste package. Use will be made of a robust, multibarrier package that will be tolerant of the full range of repository conditions.]

Other regulatory requirements in addition to those in 10 CFR 60.113 affect the waste package design, including requirements for retrievability, criticality control, consideration of alternative designs, a performance confirmation program, and specific waste package design criteria. Each of these requirements [is] considered in the design and performance assessment (PA) activities.

Compliance with the criteria for both the reference and alternative designs [is] determined by PA. PA is defined as the analysis that predicts the behavior of a system or system component under a given set of conditions. [The assessment compares the actual performance measures with those predicted by the subsystem level or total system level computational model. These performance measures are based on the allocation of performance to each of the barriers and the performance parameter goals previously established. PA provides suggested changes to these values and, therefore, interfaces with both the design and testing efforts. Both qualitative and quantitative sensitivity and uncertainty analyses is performed to show that compliance has been achieved with sufficient margin.]

[If the design did not meet the regulatory requirements with sufficient margin, the available actions are assessed. This includes modifying performance allocations, as well as re-examining those barriers for which no allocation was taken previously. For example:

- Internal canisters
- Modifying the design
- Performing additional studies to reduce uncertainties

Consideration could also be given to evaluation of the interpretation of regulatory terms and the regulations themselves.]

5.2.2.1 Containment

[Performance assessments are performed by the PA staff to determine whether the reference and alternate designs meet the requirements of SCC as defined in 10 CFR 60.113 (a) (ii) (A). The parameter values given in the latest versions of the requirements documents are compared with those generated as a result of the test program. Depending on the material, these tests include general corrosion and low-temperature oxidation, mechanical degradation, mechanical toughness under repository conditions, metallurgical stability, galvanic effects, stress corrosion cracking, and localized corrosion. The fabrication histories of the prototype containers and the various barriers are reviewed to confirm that the specifications have been met. Particular attention is paid to the nondestructive examination of closures.]

[The assessments use individual mechanistic waste package degradation codes, to be developed by the Waste Package Development staff, that is incorporated into an overall waste package performance code. The assessments include a range of environmental scenarios. These assessments permit the calculation of the number of failures during the containment period, as well as the potential for early failures. Both qualitative and quantitative sensitivity, and uncertainty analyses are performed to show whether compliance has been achieved with sufficient margin. The result is compared to the performance objective for SCC to determine whether it has been met with sufficient confidence that the NRC will find that compliance has been achieved with reasonable assurance. The potential release of radionuclides as a result of the

calculated failures is evaluated using source terms developed for each scenario by the waste form performance activities.]

5.2.2.2 Release Rate

[Performance assessments are performed to determine whether the reference and alternate designs meet the requirements of controlled release as defined in 10 CFR 60.113. The assessments include a range of environmental scenarios. Release is calculated based on waste package and waste form computational models. The potential release of radionuclides as a result of the calculated failures is evaluated using source terms developed for each scenario using the waste form performance (i.e., source term) data. However, compliance focuses on the release from the EBS and not on the individual waste packages. The computational models include gaseous releases and the diffusional releases from the packages and the EBS based on the most likely ground-water migration processes. These models are integrated over all of the likely processes as a function of time to determine the release from the EBS.]

[The assessment compares the actual performance measures with those predicted by the subsystem level computational model. These performance measures are based on the allocation of performance to each of the barriers and the performance parameter goals previously established. Performance assessment provides suggested changes to these values and therefore, interfaces with both the design and testing efforts. Both qualitative and quantitative sensitivity and uncertainty analyses are performed to show that compliance has been achieved with sufficient margin. Analyses are also performed for the alternative design to show whether it provides comparable or longer radionuclide isolation.]

5.2.3 Radiation Protection

Skeleton text has not been developed for this subsection.

REFERENCES

1. ASTM C 1174-91, "Standard Practice for Prediction of the Long-Term Behavior of Waste Package Materials Including Waste Forms Used in the Geologic Disposal of High-Level Nuclear Waste," American Society of Testing and Materials Designation.

2. R. B. Stout and H. R. Leider, Editors, "Preliminary Waste Form Characteristics Report," Version 1, October 1991, Lawrence Livermore National Laboratory.

3. YMP/92-11, "Waste Package Implementation Plan, " Rev. 0, February 1993.

Table 5.2A. EBS Design Requirements, Parameters, and Goals

Table 5.2B. Projected Radiation Exposure to Workers and Public

Table 5.2C. Results of Containment Performance Objective Evaluation

Table 5.2D. Results of Release Rate Performance Objective Evaluation

Figure 5.2A. Evaluation of EBS to Contain Radionuclides

Figure 5.2B. Evaluation of EBS to Limit Radionuclide Release

MGDS Annotated Outline Information Need Form
Form A: Information Request

Date: 5/28/93

1. Log number: **INN 5.2-001**
2. Section no. & title: **5.2 ASSESSMENT OF COMPLIANCE WITH 10 CFR PART 60**
3. Lead author & phone no: **Hugh Benton (702) 794-1891**
4. Information request date: **3/19/93**
5. Work location: **Las Vegas, Nevada**
6. Type of information needed:

   Handling design and testing results
7. What is the information needed for?

   Verification of compliance with waste package handling requirements
8. What group is the probable information supplier?

   Waste Package
9. When is the information needed?

   1997
10. What kind of related information is already available in references, etc.?

---

11. Response by (name):
12. Response date:
13. Response:

The above Annotated Outline text is guidance that may be used for the future development of an MGDS facility License Application.

MGDS Annotated Outline Information Need Form
Form A: Information Request

Date: 5/28/93

1. Log number: **INN 5.2-002**
2. Section no. & title: **5.2 ASSESSMENT OF COMPLIANCE WITH 10 CFR PART 60**
3. Lead author & phone no: **Hugh Benton (702) 794-1891**
4. Information request date: **3/19/93**
5. Work location: **Las Vegas, Nevada**
6. Type of information needed:

   Calculations of k_{eff}
7. What is the information needed for?

   Show that k_{eff} requirement has been met.
8. What group is the probable information supplier?

   Waste Package
9. When is the information needed?

   1997
10. What kind of related information is already available in references, etc.?

    Codes to perform calculations are available.

---

11. Response by (name):
12. Response date:
13. Response:

MGDS Annotated Outline Information Need Form Date: 5/28/93
Form A: Information Request

1. Log number: **INN 5.2-003**
2. Section no. & title: **5.2 ASSESSMENT OF COMPLIANCE WITH 10 CFR PART 60**
3. Lead author & phone no: **Hugh Benton (702) 794-1891**
4. Information request date: **3/19/93**
5. Work location: **Las Vegas, Nevada**
6. Type of information needed:

   Unique label design
7. What is the information needed for?

   To provide Waste Package identification at least to the end of the period of retrievability.
8. What group is the probable information supplier?

   Waste Package
9. When is the information needed?

   1997
10. What kind of related information is already available in references, etc.?

---

11. Response by (name):
12. Response date:
13. Response:

MGDS Annotated Outline Information Need Form
Form A: Information Request

Date: 5/28/93

1. Log number: **INN 5.2-004**

2. Section no. & title: **5.2 ASSESSMENT OF COMPLIANCE WITH 10 CFR PART 60**

3. Lead author & phone no: **Hugh Benton (702) 794-1891**

4. Information request date: **3/19/93**

5. Work location: **Las Vegas, Nevada**

6. Type of information needed:

   How to evacuate water from Waste Packages

7. What is the information needed for?

   To achieve the performance objectives relating to high-level waste

8. What group is the probable information supplier?

   Waste Package

9. When is the information needed?

   1997

10. What kind of related information is already available in references, etc.?

---

11. Response by (name):

12. Response date:

13. Response:

MGDS Annotated Outline Information Need Form

Date: 5/28/93

Form A: Information Request

1. Log number: **INN 5.2-005**
2. Section no. & title: **5.2 ASSESSMENT OF COMPLIANCE WITH 10 CFR PART 60**
3. Lead author & phone no: **Hugh Benton (702) 794-1891**
4. Information request date: **3/19/93**
5. Work location: **Las Vegas, Nevada**
6. Type of information needed:

   Retrievability design options
7. What is the information needed for?

   To ensure that retrievability is an option throughout waste emplacement
8. What group is the probable information supplier?

   Waste Package
9. When is the information needed?

   1997
10. What kind of related information is already available in references, etc.?

---

11. Response by (name):
12. Response date:
13. Response:

The above Annotated Outline text is guidance that may be used for the future development of an MGDS facility License Application.

MGDS Annotated Outline Information Need Form
Form A: Information Request

Date: 5/28/93

1. Log number: **INN 5.2-006**

2. Section no. & title: **5.2 ASSESSMENT OF COMPLIANCE WITH 10 CFR PART 60**

3. Lead author & phone no: **Hugh Benton (702) 794-1891**

4. Information request date: **3/19/93**

5. Work location: **Las Vegas, Nevada**

6. Type of information needed:

   EBS design options allowing for a performance confirmation program

7. What is the information needed for?

   To permit implementation of a performance confirmation program

8. What group is the probable information supplier?

   Waste Package

9. When is the information needed?

   1997

10. What kind of related information is already available in references, etc.?

---

11. Response by (name):

12. Response date:

13. Response:

MGDS Annotated Outline Information Need Form

Date: 5/28/93

Form A: Information Request

1. Log number: **INN 5.2-007**
2. Section no. & title: **5.2 ASSESSMENT OF COMPLIANCE WITH 10 CFR PART 60**
3. Lead author & phone no: **Hugh Benton (702) 794-1891**
4. Information request date: **3/19/93**
5. Work location: **Las Vegas, Nevada**
6. Type of information needed:

   A model describing the potential pre-conditioning of the glass surface by hot humid air.
7. What is the information needed for?

   To describe the long term dissolution behavior of HLW glass over time.
8. What group is the probable information supplier?

   Waste Package
9. When is the information needed?

   1997
10. What kind of related information is already available in references, etc.?

---

11. Response by (name):
12. Response date:
13. Response:

MGDS Annotated Outline Information Need Form
Form A: Information Request

Date: 5/28/93

1. Log number: **INN 5.2-008**

2. Section no. & title: **5.2 ASSESSMENT OF COMPLIANCE WITH 10 CFR PART 60**

3. Lead author & phone no: **Hugh Benton (702) 794-1891**

4. Information request date: **3/19/93**

5. Work location: **Las Vegas, Nevada**

6. Type of information needed:

   Gap inventory of radionuclides in spent fuel.

7. What is the information needed for?

   Determine rapid release fraction as input into source term.

8. What group is the probably information supplier?

   Waste Package

9. When is the information needed?

   1997

10. What kind of related information is already available in references, etc.?

    Data available for standard spent fuel only, not extended burnup spent fuel.

---

11. Response by (name):

12. Response date:

13. Response:

Section 6.2 System Description

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LIST OF INFORMATION REQUESTS

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INN 6.2-001	Documentation of Potential Conceptual Models
INN 6.2-002	Listing of calculational models used for PA Iteration 3 and conceptual models they contain to complete Tables 6.2A - 6.2F
INN 6.2-003	Listing of calculational models used for PA Iteration 3 and conceptual models they contain to complete Table 6.2G
INN 6.2-004	The EPA standard for the Yucca Mountain Site
INN 6.2-005	Potential Data requirements for biosphere processes and events
INN 6.2-006	Processes and events considered for undisturbed performance in iteration 2 of performance assessment
INN 6.2-007	Analysis of potentially disruptive processes and events and the location of their occurrence in order to effect long-term repository behavior

6.2 SYSTEM DESCRIPTION

This section describes the conceptual models, and processes and events that are analyzed to assess the overall repository system performance. The system, as used in this Section, consists of the geologic units and the hydrogeologic units within the controlled area and the influence (on the system) of natural processes and events, thermal loading, and human-initiated processes and events over the next 10,000 years and beyond. The fluid flow within the controlled area is related to the regional flow system (described in Chapter 3) where necessary to define boundary conditions for analyses and is influenced by events and process that occur both within the controlled area and the region.

6.2.1 Conceptual Models

[The potential conceptual model alternatives that could be used for evaluation of system performance are developed and documented (TBD-INN 6.2-001).] Conceptual models considered describe part or all of the following system elements: the engineered barrier system (including the waste package), the repository as influenced by thermal loading, liquid and gas flow in the unsaturated zone, liquid flow in the saturated zone, radionuclide transport in both the unsaturated and saturated zones, and the biosphere. [The potential conceptual models that are considered are screened and either rejected or incorporated into the calculational models that are used in the overall system performance assessment that is presented in this License Application (TBD-INN 6.2-001).]

[Tables 6.2.A through 6.2.F provide a summary of the conceptual models in the categories of waste package, rock mechanics, unsaturated flow, saturated flow, radionuclide transport and biosphere, respectively. Table 6.2.G provides the references for each category that justify elimination of the potential conceptual models that are not considered in the SAR (TBD-INN 6.2-002 and INN 6.2-003). A detailed discussion of the elimination of alternative conceptual models is contained in the sections that follow.]

6.2.2 Potentially Disruptive Processes and Events

[The credible potentially disruptive processes and events that could reasonably affect the geologic repository over the next 10,000 years are presented in Table 6.2H (TBD-INN 6.2-007).] These processes and events are categorized by causes, which include tectonic, geomorphic, climatic, and anthropogenic. Anthropogenic effects are either repository related or related to human activities. [Table 6.2H also indicates the location (TBD-INN 6.2-007) in which each of the processes and events are a consideration (i.e., could potentially affect the long term behavior of the repository), and the general effects that could be expected from the process or event.] Each of the processes and events is discussed by the category of its root cause, its expected location, and its effect on the post-closure performance of the overall system.

Processes and events that are caused by tectonics are uplift/subsidence/tilting, folding, faulting, seismicity, and volcanism. Each of these could alter the ground-water flow pathways or hydraulic conductivity which could affect ground-water flow, gas flow, and radionuclide transport to the accessible environment. Volcanism could affect the repository through magmatic intrusion into the emplacement area, entrainment of waste, and ejection of radionuclides into the biosphere. Intrusion of magma into an aquifer could cause steam that could travel along faults, fracture zones, or zones of higher hydraulic conductivity to reach the repository. The steam could increase corrosion rates, leaching, and radionuclide transport. The tectonic processes and events, uplift/subsidence/tilting, folding, faulting, and seismicity within the region could alter flow paths from the repository through changes in the regional ground-water flow patterns or local changes in the water table elevation. Seismicity in the region and faulting within the controlled area could increase hydraulic conductivities and release perched ground water or decrease travel time from the repository to the accessible environment. In addition to hydrologic and travel time considerations, regional seismicity can induce mass gravity movements (e.g., landslides).

Geomorphic processes and events considered are erosion and mass gravity movements such as landslides. Erosion could expose waste over long periods of time (millions of years) or cause oversteepening of slopes, making them more susceptible to mass gravity movements (YMP/92-

41-TPR). Mass gravity movements can create dams and ponds which would increase infiltration and water percolation through the repository. A reduction of depth of the repository caused by erosion or mass gravity movement could also alter flow paths in the unsaturated zone which could affect the repository. For erosion or mass gravity movements to affect the repository significantly, they would have to occur above or nearly above the emplacement area within the controlled zone. [Because of the potential for lateral flow associated with perched ground-water zones, erosion and mass gravity movements within the controlled zone are considered.]

Climate change could cause increased precipitation and increased infiltration which would increase the amount of water and water vapor moving through the repository. This increase could cause an increase in water table elevation and changes in ground-water flow paths. As discussed previously, increased precipitation could result in increased erosion. Increased infiltration could decrease ground-water travel time, increase leaching, and cause water table rise, all of which are important within the controlled area. Increased infiltration in the region could alter regional ground-water flow patterns, which could affect flow paths.

Repository-caused processes and events include thermomechanical response of the rock mass surrounding the emplacement area, and thermally induced geochemical changes that could increase hydraulic conductivity. Increased hydraulic conductivity could increase ground-water flow, gas flow, and radionuclide transport. Geochemical alteration associated with the long-term thermal pulse could change fracture fillings and/or matrix minerals and potentially reduce sorption of radionuclides in the repository near field. Geochemical changes could potentially extend beyond the emplacement area and into the controlled area. [For this reason, geochemical changes are considered within the controlled area in order to examine the potential significance of these smaller effects beyond the emplacement area.]

The undisturbed repository behavior could be changed through future human actions. Human activities considered are intrusion, induced infiltration, ground-water withdrawal, and weapons testing. Intrusion could result from drilling (either vertical or lateral) into the emplacement area or from mining into contaminated rock within a contaminated ground-water plume which could

extend from the emplacement area. To meet the requirements of the EPA Standard (TBD-INN 6.2-004), and because drilling and mining in search of natural resources could alter flow paths, intrusion is considered within the controlled area. Human activities could increase infiltration from water spreading, underground injection of water, or construction of dams and ponds within the controlled area. Ground-water withdrawal could alter the direction of flow and/or the rate of flow along flow paths. The potential for weapons testing over the next 10,000 years in the vicinity of the repository could also alter water and gas flow paths.

6.2.3 Undisturbed Performance Processes and Events

The processes affecting performance of the repository in its undisturbed state are considered to be those naturally occurring processes at the Yucca Mountain site and its vicinity which can be influenced by the construction of the facility, the thermal pulse, and any release of radioactive materials over the next 10,000 years and beyond. The processes include physical and chemical processes such as underground flow of fluids and transport of contaminants. These processes are affected by thermal loading and geochemical/chemical behavior of waste and waste package materials interacting with rock, gas, and water over long periods of time. The natural processes are affected by repository-induced processes and are also influenced by events expected to occur over the next 10,000 years, such as seismicity and climatic change.

Processes and events affecting the undisturbed waste package that are considered for performance are [presented in Table 6.2I.] To provide insight into the level of detail being considered for the waste package processes, Table 6.2J presents the potential data requirements necessary for analysis of these processes and events. Each entry in Table 6.2J and in subsequent data Tables (in this section) may represent either a single value for each material or an entire data set (e.g., the number of data points represented for each line of the data Tables is not constant; the radionuclide inventory [represented by the first line of Table 6.2J] contains the number of curies over time of each radionuclide in the repository for each waste form).

The repository and near-field undisturbed processes and events considered for performance are [presented in Table 6.2K.] These include the mechanical, hydrologic, and geochemical responses of the repository and the near field host rock to the thermal and chemical effects of the waste. For insight into the level of detail of analyses of these processes and events, the potential sets of data required are [presented in Table 6.2L.] Because of the similarity of these data sets for waste package gap filler and backfill to the data necessary for seals, the data sets necessary for evaluation of repository seals are also [presented in Table 6.2J.]

The biosphere processes and events affecting the repository in its undisturbed state that are considered for performance are [presented in Table 6.2M.] Potential data sets necessary for analysis of processes and events have been partially compiled (Table 6.2N). The remaining data for Table 6.2N will be supplied through [TBD-INN 6.2-005.] Because of the importance of fluid flow and transport processes between the waste and the accessible environment, these processes and events are [presented in greater detail in Tables 6.2O and 6.2P], respectively. The potential data sets required for analysis of fluid flow and transport are presented in Tables 6.2Q and 6.2R, respectively. For both fluid flow and transport, the data sets for unsaturated conditions are [presented in Tables 6.2O through 6.2R,] and these data sets will be simplified for saturated conditions.

[The processes and events considered for undisturbed performance at the Yucca Mountain site are summarized in Table 6.2S (TBD-INN 6.2-006).] These are categorized by cause and expected location of consideration (i.e., within the emplacement area, repository disturbed zone, controlled area, etc.). The potential effects of the processes and events are also tabulated. [Table 6.2S and other Tables in this section will be completed or updated through INN 6.2-006.]

REFERENCES

Table 6.2C. Conceptual Models Used for Analysis of Unsaturated Flow

Calculational Model	Conceptual Models
TOUGH2	Porous Media Double Porosity Dual Continuum

Note: Tables 6.2A through 6.2F are similar in design and only 6.2C is shown here. These tables will be completed using INN 6.2-002.

Table 6.2G. Justification of Conceptual Models Not Included in the Performance Assessment

Area	Conceptual Models Eliminated	Documentation
Waste Package	Examples	Reference for each area which justifies elimination
Rock Mechanics		
Unsaturated Flow	Discrete Fracture (etc)	
Saturated Flow		
Radionuclide Transport		
Biosphere		

Note: This Table will be completed using INN 6.2-003.

Table 6.2H. Location and General Effects of Potential Disruptive Processes and Events

Cause	Process/Event	Location	General Effects
Tectonic	• Uplift/Subsidence/Tilting	Region	Alteration of flow paths
	• Folding	Region	Alteration of flow paths
	• Faulting	Controlled area and region	Alteration of flow paths
	• Seismicity	Region	Alteration of flow paths
	• Volcanism		
	- magmatic intrusion	Emplacement area	Waste entrainment
	- hydrothermal intrusion	Controlled area	Corrosion/leaching/migration
	• Mass gravity movements	Region	Alteration of flow paths
Geomorphic	• Erosion	Controlled area	Reduced depth to waste, increased infiltration
	• Mass Gravity Movements		Reduced travel time
	- Dams & Ponds		
Repository	• Thermomechanical	Disturbed zone	Alteration of flow paths
	• Geochemical	Disturbed zone and controlled area	Alteration of flow path and alteration of sorption
Climatic	• Infiltration	Controlled area and region	Decreased travel time, increased leaching, and water table rise
	• Erosion/Mass Gravity - Dams & Ponds	Controlled area	Increased infiltration
Human	• Intrusion		
	- Drilling	Controlled area	Waste exhumation, alteration of flow paths, and drinking water wells
	- Mining	Controlled area	Exhumation of contaminated rock
	• Infiltration		
	- Ground-water injection/water spreading	Controlled area	Increased infiltration, alteration of flow paths
	- Dams & Ponds	Controlled area	Increased infiltration
	• Weapons Testing	Controlled area	Alteration of flow paths

Note: This Table will be completed based on analyses in (TBD-INN 6.2-007).

Table 6.2I. Waste Package Processes and Events for Undisturbed Performance

Waste Package Environment Processes

- Thermal
- Mechanical
- Radiation
- Geochemical
- Hydrodynamic

Waste Package Failure Processes

- Uniform corrosion
- Pitting corrosion
- Stress crack corrosion
- Mechanical
- Hydrogen embrittlement
- Oxidation

Waste Form Release Processes

- Gaseous release
  - Instantaneous
  - Gradual
- Aqueous release processes
  - Solubility controlled
  - Alteration controlled

Note: This Table will be completed using INN 6.2-006.

Table 6.2J. Potential Waste Package Data Requirements

Waste Form

- Radionuclide Inventory
  - Percent in matrix
  - Percent in gap
  - Percent in grain and grain boundary
  - Percent in cladding
  - Fission history
- Chemical properties
  - Percent of fuel/waste wet
  - Radiolysis
  - Colloid formation
  - Solubility
  - Fuel and glass alteration rate
  - Fuel and glass composition
  - Radiation induced changes
  - Thermally induced changes
  - Corrosion induced changes
- Thermal properties
  - Density
  - Specific heat
  - Thermal conductivity
- Radiation properties
  - Densities
  - Attenuation cross sections

Table 6.2J. Potential Waste Package Data Requirements (Continued)

Waste Package

- Thermal properties
  - Density
  - Specific heat
  - Thermal conductivity
- Radiation properties
  - Densities
  - Attenuation cross sections
- Mechanical properties
  - In-situ stresses
  - Moduli (elasticity, etc.)
  - Poisson's ratio
- Corrosion properties
  - Uniform corrosion parameters
  - Pitting parameters
  - Stress cracking parameters
  - Oxidation parameters
  - Chemical properties
  - Corrosion depth to failure
  - Electrochemical properties
  - Microbiological properties

Table 6.2J. Potential Waste Package Data Requirements (Continued)

Gap Filler, Backfill, and Seals[1]

- Hydrodynamic properties
  - Porosity
  - Tortuosity
  - Permeability
  - Saturation
  - Retardation
  - Diffusion coefficients
- Water chemistry
  - Radiolysis
  - Radiation induced changes
  - Temperature induced changes
  - Colloid formation
  - Corrosion induced changes
- Thermal properties
  - Density
  - Specific heat
  - Thermal conductivity
- Radiation properties
  - Density
  - Specific heat
  - Thermal conductivity

Geometry

- Waste package
- Gap, gap filler, and backfill
- Placement

[1] Technically, data sets for evaluation of repository seals should be presented in Table 6.2L but are presented here because of their similarity to filler and backfill.

Table 6.2J. Potential Waste Package Data Requirements (Continued)

Boundary and Initial Conditions

- Temperature
- Manufactured defects
- Mechanical failure
- Chemical composition
- In-situ stress
- Water saturation
- Fluid flux
- Thermal flux
- Radiation flux

Note: This Table will be completed using INN 6.2-006.

Table 6.2K. Repository and Near-Field Processes and Events for Undisturbed Performance

Heat Transfer

- Convection
- Radiation
- Conduction

Mechanical Response

- Rock mass deformation
- Joint deformation
- Rock failure
- Seal deformation[2] see Table 6.2J.

Hydrologic Response

- Water and water vapor flow
- Gas flow
- Permeability change

Geochemical Response

- Precipitation/dissolution reactions
- Colloid formation
- Aqueous reactions
- Ion exchange
- Redox reactions
- Adsorption/desorption
- Rock/water interactions

Note: This Table will be completed using INN 6.2-006.

[2] For data sets needed for evaluation of repository seals, see Table 6.2J under Gap Filler, Backfill, and Seals.

Table 6.2L. Potential Repository and Near-Field Data Requirements

Heat Transfer

- Heat transfer as a function of time
- Convective heat transfer as a function of temperature
- Radiative heat transfer
- Conduction

  - Rock mass bulk properties
  - Rock mass heat capacity as a function of saturation
  - Rock mass thermal conductivity
  - Air density
  - Air heat capacity
  - Air thermal conductivity
  - Water density
  - Water heat capacity
  - Water thermal conductivity

Mechanical Response

- Intact rock and rock mass properties

  - Density
  - Elastic constants (anisotropy)
  - Internal friction properties
  - Deformation modulus (time, temperature, stresses)
  - Compressive strength (time, temperature, stresses)
  - Tensile strength (time, temperature, stresses)

- Effects of damage function on rock mass properties
- Rock mass properties under dynamic loading

Table 6.2L. Potential Repository and Near-Field Data Requirements (Continued)

Hydrologic Response

- Saturated water intrinsic permeability
- Permeability as a function of water saturation
- Capillary pressure as a function of water saturation
- Total porosity
- Liquid fracture matrix coupling function
- Thermal expansion
- Thermal conductivity
- Specific heat

Geochemical Response

- Dispersivity
- Minerals/ petrologic description
- Diffusion coefficients
- Equilibrium distribution coefficients
- Chemical thermodynamic database
- Fluid chemistry

Boundary Conditions

- Pressure or hydraulic potential
- Water saturation
- Water and gas flux
- Overburden loading
- Temperature
- Thermal flux

Initial Conditions

- Ambient stresses
- Ambient temperature
- Fluid pore pressure
- Joint geometry

Note: This Table will be completed using INN 6.2-006.

Table 6.2M. Biosphere Processes and Events for Undisturbed Performance

- Climate variation
  - Precipitation change
- Surface Water
  - Rivers and streams
  - Lakes and ponds
- Dose to man and environment
  - Inhalation
  - Ingestion
  - Immersion
  - Direct radiation
  - Food chain transport
  - Population

Note: This Table will be completed using INN 6.2-006.

Table 6.2N. Potential Biosphere Data Requirements

Fluid Flow
(See Table 6.2P)

Radionuclide Transport
(See Table 6.2R)

Note: This Table will be completed using INN 6.2-005.

Table 6.2O. Fluid Flow Processes and Events for Undisturbed Performance

Porous Flow

- Gas, vapor, liquid

Fracture flow

- Gas, vapor, liquid

Fracture/matrix coupling

- Equilibrium and disequilibrium

Gas, vapor, liquid

Thermal effects

- Thermal expansion
- Block slip (hydraulic conductivity change)

Geochemical effects

- Precipitation/dissolution reactions

Note: This Table will be completed using INN 6.2-006.

Table 6.2P. Potential Fluid Flow Data Requirements

Matrix and Fracture Material Properties

- Liquid fluid phases

  -Saturated water intrinsic permeability
  -Relative permeability as a function of water saturation
  -Capillary pressure as a function of water saturation
  -Total porosity
  -Liquid fracture - matrix coupling term
  -Fracture water saturation delay (model parameter)

- Gas fluid phases

  -Saturated gas intrinsic permeability
  -Relative permeability as a function of gas saturation
  -Capillary pressure as a function of gas saturation
  -Gas fracture - matrix coupling function
  -Fracture gas saturation delay
  -Dissolved gas in liquid as a function of temperature and pressure
  -Base vapor - gas diffusion coefficients
  -Temperature dependent diffusion exponent
  -Tortuosity and related factors
  -Mass fraction phase factor

- Thermal effects of porous medium for water and gas

  -Thermal expansion vs. saturation
  -Thermal conductivity vs. saturation
  -Specific heat vs. saturation

- Fracture properties (individual and sets)

  -Dimensions
  -Orientations
  -Connectivity

Table 6.2P. Potential Fluid Flow Data Requirements (Continued)

Fluid Properties

- Liquid densities as a function of temperature, pressure, concentration
- Gas densities as a function of temperature, pressure, concentration
- Vapor densities as a function of temperature and pressure
- Dynamic liquid viscosities as a function of temperature, pressure, concentration
- Dynamic gas viscosities as a function of temperature, pressure, concentration
- Dynamic vapor viscosities as a function of temperature and pressure
- Thermal conductivity as a function of temperature and pressure
- Specific heat as a function of temperature, pressure, concentration
- Thermophysical water properties (steam tables)

Boundary Conditions

- Pressure or hydraulic potential conditions
- Temperature conditions
- Fluid saturations
- Flux of fluid and temperature

Initial Conditions

- (same as boundary conditions)

Geometry

- Hydrologic unit contacts
- Fault geometry
- Discrete fracture geometry

Note: This Table will be completed using INN 6.2-006.

Table 6.2Q. Transport Processes and Events for Undisturbed Performance

- Diffusion
- Dispersion
- Retardation
  - Ion exchange
  - Adsorption/desorption
  - Precipitation/dissolution
  - Matrix diffusion
  - Chelation
- Geochemical reactions
- Radioactive decay

Note: This Table will be completed using INN 6.2-006.

Table 6.2R. Potential Transport Data Requirements

Material Characteristics (matrix and fracture)

- Dispersivities
- Total porosity
- Effective porosity
- Diffusivity
- Specific density
- Fracture configuration from flow model

Fluid Properties

- Liquid densities as a function of temperature, pressure, concentration
- Dynamic liquid viscosities as a function of temperature, pressure, concentration
- Thermal conductivity as a function of temperature, pressure, concentration
- Diffusion coefficient as a function of temperature, pressure, concentration

Geochemistry

- Minerals/petrologic description
- Sorption coefficients
- Matrix diffusion coefficients
- Equilibrium distribution coefficient
- Chemical thermodynamic database
- Sorption isotherms
- Natural colloids, organics
- Actinide polymerization
- Reaction rates

Liquid Phase

- Flow vector fields
- Saturation distribution
- Temperature distributions
- Condensed water vapor fields

Table 6.2R. Potential Transport Data Requirements (Continued)

Gas Phase

- Water vapor flow fields
- Flow vector fields
- Saturation distributions
- Temperature distribution

Boundary Conditions

- Concentrations
- Contaminant fluxes

Initial Conditions

- Concentrations
- Contaminant fluxes
- Radionuclide inventory

Geometry

- From flow model

Note: This Table will be completed using INN 6.2-006.

Table 6.2S. Summary of Processes and Events for Undisturbed Performance[3]

Cause	Process/Event	Where Considered	General Effects
Waste	• Heat transfer	Emplacement area and controlled area	Thermally induced fluid flow
	• Radiolysis	Emplacement area	Geochemical changes
	• Heat transfer	Disturbed zone	Stress/strain alterations
Corrosion/Geochemical	• Waste package degradation	Emplacement area	Gaseous release and/or exposure
Underground Opening	• Creep	Disturbed zone	Spalling and/or structural collapse
Geochemical	• Waste leaching	Emplacement area	Mobilization of radionuclides
	• Sorption	Between the waste form and the accessible environment	Retardation of radionuclides
	• Colloid formation	Emplacement area	Mobilization of radionuclides
	• Precipitation/dissolution	Along flow paths from waste form to accessible environment	Changes in fluid conductivity
	•		
Tectonic	• Seismicity	Within the controlled area	Alteration of flow paths
	•		
Climatic change	• Infiltration	Within the controlled area	Increased fluid flow and water table rise
		Within the region	Alteration of flow paths
	• Flooding	Within the controlled area	Increased fluid flow
Radionuclide Migration	• Dose-to-man	At the accessible environment	Increased health effects
Fluid Flow	• Gaseous and/or liquid transport of radionuclides	Within the controlled area	Migration of contaminants to accessible environment
Diffusion	• Matrix diffusion	Within the controlled area	Retardation of containment migration

[3] Table will be completed using the analyses in INN 6.2-006.

MGDS Annotated Outline Information Need Form Date: 5/28/93

Form A: Information Request

1. Log number: **INN 6.2-001**
2. Section no. & title: **6.2 SYSTEM DESCRIPTION**
3. Lead author & phone no: **Jim Duguid (703) 204-8851**
4. Information request date: **2/21/92**
5. Work location: **Vienna, Virginia**
6. Type of information needed:

   Documentation of potential conceptual models.
7. What is the information needed for?

   As a reference to demonstrate that all potentially conceptual models for Yucca Mountain were considered.
8. What group is the probable information supplier?

   Performance Assessment
9. When is the information needed?

   December 1994.
10. What kind of related information is already available in references, etc.?

---

11. Response by (name):
12. Response date:
13. Response:

MGDS Annotated Outline Information Need Form
Form A: Information Request

Date: 5/28/93

1. Log number: **INN 6.2-002**

2. Section no. & title: **6.2 SYSTEM DESCRIPTION**

3. Lead author & phone no: **Jim Duguid (703) 204-8851**

4. Information request date: **2/21/92**

5. Work location: **Vienna, Virginia**

6. Type of information needed:

   Listing of calculational models used for PA Iteration 3 and conceptual models they contain.

7. What is the information needed for?

   Completion of Tables 6.2A through Table 6.2F.

8. What group is the probable information supplier?

   Performance Assessment, Bob Andrews, M&O.

9. When is the information needed?

   December 1994.

10. What kind of related information is already available in references, etc.?

---

11. Response by (name):

12. Response date:

13. Response:

MGDS Annotated Outline Information Need Form

Date: 5/28/93

Form A: Information Request

1. Log number: **INN 6.2-003**
2. Section no. & title: **6.2 SYSTEM DESCRIPTION**
3. Lead author & phone no: **Jim Duguid (703) 204-8851**
4. Information request date: **2/21/92**
5. Work location: **Vienna, Virginia**
6. Type of information needed:

   Listing of calculational models used for PA Iteration 3 and conceptual models they contain.

7. What is the information needed for?

   Completion of Table 6.2G.

8. What group is the probable information supplier?

   Performance Assessment, Bob Andrews, M&O.

9. When is the information needed?

   December 1994.

10. What kind of related information is already available in references, etc.?

---

11. Response by (name):
12. Response date:
13. Response:

MGDS Annotated Outline Information Need Form
Form A: Information Request

Date: 5/28/93

1. Log number: **INN 6.2-004**

2. Section No. & Title: **6.2 SYSTEM DESCRIPTION**

3. Lead Author & Phone No.: **Jim Duguid (703) 204-8851**

4. Information request date: **2/02/93**

5. Work Location: **Vienna, Virginia**

6. Type of information needed:

   The EPA standard for the Yucca Mountain site.

7. What is the information needed for? (e.g., Safety Analysis Section 3.2):

   To provide release/dose requirements for the high-level waste repository at Yucca Mountain. Currently 40 CFR 191 is being used until new standards are available.

8. What group is the probable information supplier?

   The Environmental Protection Agency (EPA).

9. When is the information needed?

   1995

10. What kind of related information is already available in references, etc.? (List any known, related information sources):

    40 CFR 191

---

11. Response by (name):

12. Response date:

13. Response:

MGDS Annotated Outline Information Need Form Date: 5/28/93
Form A: Information Request

1. Log number: **INN 6.2-005**
2. Section No. & Title: **6.2 SYSTEM DESCRIPTION**
3. Lead Author & Phone No.: **Jim Duguid (703) 204-8851**
4. Information request date: **2/21/92**
5. Work Location: **Vienna, Virginia**
6. Type of information needed:

   Potential Data requirements for biosphere processes and events
7. What is the information needed for? (e.g., Safety Analysis Section 3.2):

   Completion of Table 6.2N
8. What group is the probable information supplier?

   Performance Assessment Group, Bob Andrews, M&O
9. When is the information needed?

   December 1993
10. What kind of related information is already available in references, etc.? (List any known, related information sources):

---

11. Response by (name):
12. Response date:
13. Response:

The above Annotated Outline text is guidance that may be used for the future development of an MGDS facility License Application.

MGDS Annotated Outline Information Need Form
Form A: Information Request

Date: 5/28/93

1. Log number: **INN 6.2-006**

2. Section No. & Title: **6.2 SYSTEM DESCRIPTION**

3. Lead Author & Phone No.: **Jim Duguid (703) 204-8851**

4. Information request date: **2/21/92**

5. Work Location: **Vienna, Virginia**

6. Type of information needed:

   Processes and events considered for undisturbed performance in iteration 2 of performance assessment.

7. What is the information needed for? (e.g., Safety Analysis Section 3.2):

   Completing Table 6.2S and updating Tables 6.2I-6.2M and 6.2O-6.2R.

8. What group is the probable information supplier?

   Performance Assessment

9. When is the information needed?

   December 1993

10. What kind of related information is already available in references, etc.? (List any known, related information sources):

---

11. Response by (name):

12. Response date:

13. Response:

MGDS Annotated Outline Information Need Form
Form A: Information Request

Date: 5/28/93

1. Log number: **INN 6.2-007**

2. Section No. & Title: **6.2 SYSTEM DESCRIPTION**

3. Lead Author & Phone No.: **Jim Duguid (703) 204-8851**

4. Information request date: **3/11/93**

5. Work Location: **Vienna, Virginia**

6. Type of information needed:

   Analysis of potentially disruptive processes and events and the location of their occurrence in order to effect long-term repository behavior.

7. What is the information needed for? (e.g., Safety Analysis Section 3.2):

   Completing Table 6.2H and updating Tables 6.2I-6.2M and 6.2O-6.2R.

8. What group is the probable information supplier?

   Performance Assessment

9. When is the information needed?

   December 1994

10. What kind of related information is already available in references, etc.? (List any known, related information sources):

    SNL Screening of Processes and Events

---

11. Response by (name):

12. Response date:

13. Response:

Section 6.3 Assessment of Compliance: Cumulative Release of Radioactive Materials

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF INFORMATION REQUESTS

Log #	Type of Information Needed
INN 6.3-001	Screening Criteria for Processes and Events to Modify Table 6.3-A
INN 6.3-002	Documentation of the second iteration of the Total System Performance Assessment
INN 6.3-003	The EPA standard for the Yucca Mountain Site
INN 6.3-004	Processes and events retained and a discussion of their effects on the performance assessment results
INN 6.3-005	Methods used to eliminate insignificant processes and events, processes and events that were eliminated, and the justification for elimination of each
INN 6.3-006	Method of combination of processes and events into scenarios
INN 6.3-007	Criteria used for screening scenarios
INN 6.3-008	The level of confidence necessary for screening the scenarios
INN 6.3-009	The results of the scenario screening along with the results of their analyses
INN 6.3-010	Discussion of methods used in analyses of scenarios, repository under expected conditions, and CCDFs of the results
INN 6.3-011	Probabilities of occurrence of processes and events along with the uncertainty in their determination
INN 6.3-012	Probabilities of occurrence of scenarios and processes and events along with the uncertainty in their determination
INN 6.3-013	Methods of formation of CCDFs and related uncertainty and sensitivity analyses
INN 6.3-014	Demonstration of site suitability and related analyses
INN 6.3-015	Discussion of the methods of production of the CCDF, uncertainties in its production, and alternative representations of CCDFs
INN 6.3-016	Discussion of verification and validation of all models and codes used for performance assessment including their QA documentation

6.3 ASSESSMENT OF COMPLIANCE: CUMULATIVE RELEASE OF RADIOACTIVE MATERIALS

[The purpose of this section is to discuss whether the overall performance of the repository system at Yucca Mountain complies with 10 CFR 60.112 which requires compliance with the EPA Standard for Yucca Mountain (TBD). Until the EPA Standard for Yucca Mountain is promulgated 40 CFR 191 is being followed. The performance of the overall repository system at the Yucca Mountain site is evaluated in terms of cumulative releases of radioactive materials to the accessible environment for 10,000 years after repository closure. This entire section will be completed using INN 6.3-001 and INN 6.3-002. These analyses are used to demonstrate compliance with 10 CFR 60.112. In addition, analyses are performed to determine peak releases. Although these longer-term analyses are highly uncertain, they provide some degree of assurance that rapid degradation of the overall repository system does not occur beyond the required 10,000-year analysis period. Screening of processes and events, development of scenarios, and screening of scenarios are summarized and references are provided to fully document selected processes and events, and the resulting scenarios to be analyzed.]

[Sensitivity analyses are presented to provide an understanding of parameters, conceptual models, and process uncertainty. Sensitivity analyses were performed to identify those elements of the overall system that affect the performance of the repository for each of the scenarios. Deterministic analyses combined with sensitivity analyses were conducted with process and subsystem models to demonstrate that the systems models, used to produce the Complementary Cumulative Distribution Function (CCDF) yield conservative results. Two approaches to developing the CCDF are discussed to demonstrate compliance with the requirements of the EPA Standard (TBD-INN 6.3-003). In addition, CCDFs are presented for both the disturbed and undisturbed scenarios of repository behavior. For the undisturbed case, conditions where concentrations of radionuclides reach the accessible environment by gaseous and ground-water pathways during the first 10,000 years are analyzed. Analyses also are included that demonstrate compliance with the individual protection requirements (dose from all pathways) and the ground-water protection requirements (dose from drinking water) of the EPA Standard (TBD-INN

6.3-003). The models used in the analyses are listed and their characteristics are summarized. The status of code verification and model validation is summarized and references are provided that describe verification and validation in detail. In addition, confirmatory testing (presented in Chapter 8) is cross referenced where results are expected to provide data for further validation of models.]

6.3.1 Screening of Processes and Events

6.3.1.1 Screening Criteria

[Screening criteria are designed to eliminate those processes and events that do not contribute to the CCDF or significantly to dose (TBD-INN 6.3-003), because they are physically or logically unrealistic or are expected to have trivial consequences. Initially, processes and events are eliminated from those identified in Sections 6.2.2 and 6.2.3 when on site characterization results indicate that a particular process or event does not or cannot occur in the vicinity of the site. At this stage, processes and events that are known to occur in the region but have not been found at the site are retained. Processes and events that clearly have probabilities of occurrence lower than 10^{-8} in a given year or where they are physically or logically unrealistic and not credible are eliminated. Where uncertainties in the probability of occurrence are high, processes and events are retained. The criterion that processes or events must significantly alter the releases of radionuclides over 10,000 years is applied, and those processes and events showing no significant changes in release are eliminated. For example, climatic change could increase infiltration, which would increase flow through the repository and potentially increase radionuclide transport; therefore, climatic change is retained. Remaining events are combined into scenarios and appropriate process models are used, the resulting analyses are included in the CCDF and in dose calculations. Where no effect on the position of the CCDF is observed, additional processes and events are eliminated. The criteria used in screening processes and events are presented in Table 6.3A. (TBD-INN 6.3-001). This section will be rewritten based on INN 6.3-001, INN 6.3-002, and INN 6.3-003.]

6.3.1.2 Selected Processes and Events

[The processes and events which passed the screening criteria in Section 6.3.1.1 are listed in Table 6.3B (TBD-INN 6.3-004) along with the impact of the processes and events on performance assessment. These processes and events are used in the development of scenarios described in Section 6.3.2. The results of analyses using process models (models that incorporate the processes that remain after screening) and total system performance assessment models (models that incorporate abstractions of remaining processes) are presented (Table 6.3B). The level of confidence related in the effects of the processes and events on the analyses is also included in Table 6.3B. Those processes and events for which there is a low confidence in the probability of occurrence are also included.]

6.3.1.3 Justification for Elimination of Processes and Events

[Many processes and events have been eliminated from further consideration in the screening process described above. Those processes and events which are not present, have low probability of occurrence, or have no material effect on the performance of the repository, are summarized in Table 6.3C (TBD-INN 6.3-005). These analyses demonstrate that those processes and events are not present, not credible, or have no significant effect on the repository. These analyses include detailed process model evaluations as well as total system performance assessment evaluations. The level of confidence required for elimination of insignificant processes and events was determined, analyses were conducted, and the processes and events were eliminated (TBD-INN 6.3-005).] Those processes and events that were retained were used in the analyses of and in the development of scenarios, respectively.

6.3.2 Scenario Development and Screening

Scenario development and screening are the next phase of analysis after the processes and events have been evaluated. The method for developing and screening scenarios for undisturbed conditions, as well as the selected scenarios, is presented below.

6.3.2.1 Scenario Development - Undisturbed Conditions

[The method of developing scenarios for anticipated (undisturbed) conditions involves combining the processes and events selected in Section 6.3.1. Reasonable scenarios are developed by combining processes and events using the approach that is presented in _____ (TBD-INN 6.3-006). The method of constructing scenarios is presented in Figure 6.3A.]

6.3.2.2 Screening of Scenarios

[Criteria for screening the scenarios to select the significant ones or to eliminate insignificant scenarios are presented in this section along with the selected and eliminated scenarios. The scenarios were developed according to the methods shown in Figure 6.3A and screened using the methods described in TBD-INN 6.3-006. The screening was conducted using the screening criteria presented in Table 6.3D (TBD-INN 6.3-007). The screening criteria include; that the scenario must be both logically and physically possible, have a probability of occurrence greater than 10^{-8}, have a significant effect on the CCDF, and have a significant effect on doses. Guidelines provided by the NRC were incorporated into the screening criteria as appropriate. The level of confidence required to eliminate a scenario is presented in Table 6.3E. The listing of the scenarios that passed through the screening is provided in Table 6.3F. These scenarios are used in the analyses of cumulative release and dose that are required to demonstrate compliance with 10 CFR 60 and the EPA Standard (TBD-INN 6.3-003).]

6.3.3 Consequence Analysis: Estimates of Cumulative Releases

6.3.3.1 Repository Performance Results

[The Yucca Mountain Repository consequence analysis results are presented in the _____ (TBD-INN 6.3-010). The analyses indicating the suitability of the site for disposal of radioactive waste are provided in INN 6.3-010, and will be used to complete this Section. This Section will also cross reference the engineered barrier analyses contained in Chapter 5.]

6.3.3.2 Cumulative Release and Dose Analyses

[The CCDFs which provide the estimate of cumulative releases to the accessible environment are presented in Figure 6.3B (there will be one Figure for each of n scenarios, TBD-INN 6.3-010)]. The results necessary for completion of this Section will be provided by INN 6.3-010.

6.3.3.3 Methods Used for Cumulative Release and Dose Analyses

[The methods used for cumulative release and dose analyses have been previously defined in general terms in discussion of the iterative performance assessment (Section 6.1). The results from the total system models are converted to CCDFs which are shown in Figure 6.3B (there will be one Figure for each of n scenarios). A detailed discussion of the dose assessment methods can be found in (TBD-INN 6.3-010), and this material will be used to complete this Section and Table 6.3G.]

6.3.4 Probability Estimates

[The determination of which processes and events require estimates of probability of occurrence are described in detail in (TBD-INN 6.3-010). Different methods were used to develop estimates of probability of occurrence for the selected processes and events. These methods included expert judgment.] This Section and the Subsections that follow will be completed using (TBD-INN 6.3-010 through INN 6.3-012).

6.3.4.1 Probability of Occurrence of Processes and Events

The processes and events selected in Section 6.3.1.2 have a probability of occurrence which can be determined with different levels of uncertainty depending on the approach used. [These probabilities are presented in Table 6.3H (TBD-INN 6.3-011).]

6.3.4.2 Probability of Occurrence of Scenarios

The probability of occurrence of the scenarios involves a combination of the probability of occurrence of each of the processes and events included in the scenario. [These will be identified in INN 6.3-012 and used to complete Table 6.3I.]

6.3.4.3 Method of Probability Estimation

[The methods used for probability estimation are shown in Table 6.3J (TBD-INN 6.3-012).]

6.3.4.4 Probabilities of Transient Phenomena

[The methods used for determination of probabilities of transient phenomena are shown in Table 6.3K (TBD-INN 6.3-012).]

6.3.4.5 Uncertainty in Probability Estimation

The probability estimates of processes and events and the scenarios that will be developed using them contain uncertainty. [The estimation of uncertainty will be defined in INN 6.3-012, and the results will be used to complete this Section.]

6.3.4.6 Additional Discussion on Probability Estimation

[This Section contains a discussion of alternative methods of estimating probabilities and the justification of not using those methods (TBD-INN 6.3-012).]

6.3.5 Compliance Assessment for Cumulative Releases

[The compliance assessment for cumulative releases takes the iterative approach described in Section 6.0. A process of analysis and comparison of repository performance under selected scenarios to determine whether the repository complies with the appropriate release and dose standards has been adopted (TBD-INN 6.3-003). The CCDFs were developed following the methods defined in _____ (TBD-INN 6.3-009). The analyses for cumulative release indicate that the site satisfies the EPA Standards (TBD) for the selected scenarios. The conditional CCDFs for each of the scenarios are presented in Figure 6.3B (there will be one Figure for each one of the n scenarios). Sensitivity analyses of the results indicate the effect of uncertainty on the CCDFs (TBD-INN 6.3-013).]

6.3.5.1 Demonstration of Compliance with 10 CFR 60.112

[The demonstration of compliance with 10 CFR 60.112, the overall system performance objective for cumulative release, is presented in _____ (TBD-INN 6.3-014).]

6.3.5.2 Method of CCDF Formulation

[The conditional CCDFs were formulated according to the method presented in Table 6.3L (TBD-INN 6.3-015). This Section will be completed using INN 6.3-015 which will describe the method of composing the CCDF.]

6.3.5.3 Composite CCDF for Yucca Mountain

[The composite CCDF for Yucca Mountain is shown in Figure 6.3C (TBD-INN 6.3-015 and TBD-INN 6.3-009), and material contained in these reports (TBD) will be used to complete this Section.]

6.3.5.4 Uncertainties in Development of the CCDF

[The uncertainties in the Yucca Mountain CCDF are presented in Table 6.3M (TBD-INN 6.3-015), and information contained in this report (TBD) will be used to complete this Section.]

6.3.5.5 Alternative Representations of the CCDF

[The alternative representations of the CCDF are presented in _____(TBD-INN 6.3-015). This report (TBD) will be used to complete this Section.]

6.3.6 Model and Code Verification and Validation

[The information in this section on code verification and model validation will be cross referenced with Chapter 8 because many of the tests described in that Chapter will provide the basis for model validation. The results of code verification and model validation will be incorporated primarily by reference. (A summary will be included here.)]

Verification of calculational models involves comparison of results with results from analytical solutions. It includes verifying that the software is properly coded. Validation provides reasonable assurance that the model embodied in a computer code is a correct representation of the process or system for which it is intended.

[The codes to be verified and models to be validated relative to cumulative release are listed in Table 6.3N (TBD-INN 6.3-016). The models are grouped into two major categories: Total System PA and detailed process models. The validation methods for each of these categories of models varies depending on the type and level of detail of the model. An extensive discussion on the verification and validation of the various codes and models, respectively is documented in _____ (TBD-INN 6.3-016).]

REFERENCES

Table 6.3A. Screening Criteria for Retention of Processes and Events*

CRITERION	EXPLANATION
Presence	Site characterization data indicate presence of process/event at the site or within the region
Probability	Probability of occurrence is greater than 10^{-8} per year
Consequence	Process and event potentially increases radionuclide release
Consequence	Incorporation of process and event changes dose

*Processes and events that are physically or logically unrealistic and are expected to produce trivial consequences will be eliminated.

Note: This Table will be completed using INN 6.3-001 and INN 6.3-002.

Table 6.3B. List of Processes and Events Retained After Screening

Event	Impact on PA Results
1. Climatic Change	(discussion and references)
2. Human Intrusion	
Process	**Impact on PA Results**
1. Tectonism	(discussion and references)
2. Fracture Flow	
3. Gas Flow	

Note: This Table will be completed using INN 6.3-004.

Table 6.3C. Summary of Processes and Events That Were Eliminated

Process/Event Eliminated	Justification for Elimination
1. Meteor Impact	(show data, analyses, reports)
2.	
3.	
4.	

Note: This Table will be completed using INN 6.3-005.

Table 6.3D. Criteria Used for Scenario Screening

Criterion	Explanation
1. Probability	Probability of occurrence is less than 10^{-8}
2.	

Note: This Table will be completed using INN 6.3-007.

Table 6.3E. Level of Confidence Required to Eliminate Scenarios

Scenario and Description	Insignificant	Significant	Level of Confidence	Eliminate
1. -----		x		No
2. -----	x			

Note: This Table will be completed using INN 6.3-008.

Table 6.3F. Scenarios Retained After Screening

Scenario and Description	Discussion of Importance
1.	
2.	

Note: This Table will be completed using INN 6.3-009.

Table 6.3G. Description of Analytical Methods Used for Scenario Analyses

Analytical Method	Application and Remarks
1. Computer Code	
2.	

Note: This Table will be completed using INN 6.3-010.

Table 6.3H. Probability of Occurrence of Processes and Events

Process/Event	Probability of Occurrence	Uncertainty	Source
Tectonism			
Volcanism			

Note: This Table will be completed using INN 6.3-011.

Table 6.3I. Probability of Occurrence of Scenarios

Scenario	Probability/Frequency of Occurrence	Uncertainty	Source
Scenario 1			
Scenario 2			

Note: This Table will be completed using INN 6.3-012.

Table 6.3J. Method Used to Estimate Probability

Technique Used	Criteria Used	Uncertainty	Source

Note: This Table will be completed using INN 6.3-012.

Table 6.3K. Uncertainties in Determination of the Probabilities of Transient Phenomena

Scenario	Explanation Regarding Time Dependent Probability	Uncertainty	Source

Note: This Table will be completed using INN 6.3-012.

Table 6.3L. Means to Produce Complementary Cumulative Distribution Functions (CCDF)

Computer Code/Model	Source	Resultant Output and Application

Note: This Table will be completed using INN 6.3-015.

Table 6.3M. Uncertainties Remaining in the CCDF

Uncertainty	Discussion

Note: This Table will be completed using INN 6.3-015.

Table 6.3N. Verification and Validation of Computer Codes and Models

Model	Analyses	QA Status	Verified	Validated	Source
TOUGH2	UZ Flow				LBL
RIP	TSPA				Golder

Note: This Table will be completed using INN 6.3-016.

Figure 6.3A. Method of Constructing Scenarios (TBD-INN 6.3-006)

Figure 6.3B(1--n). CCDFs for Scenarios Retained (TBD-INN 6.3-009)
(Note: This will include one figure for each of the n scenarios considered.)

Figure 6.3C. Composite CCDF for Yucca Mountain (TBD-INN 6.3-015)

MGDS Annotated Outline Information Need Form Date: 5/28/93

Form A: Information Request

1. Log number: **INN 6.3-001**

2. Section no. & title: **6.3 ASSESSMENT OF COMPLIANCE: CUMULATIVE RELEASE OF RADIOACTIVE MATERIALS**

3. Lead author & phone no: **Jim Duguid (703) 204-8851**

4. Information request date: **02/21/92**

5. Work location: **Vienna, Virginia**

6. Type of information needed:

   Screening Criteria for Processes and Events to modify Table 6.3-A.

7. What is the information needed for?

   To modify Table 6.3A.

8. What group is the probable information supplier?

   SNL, George Barr

9. When is the information needed?

   December 1993

10. What kind of related information is already available in references, etc.?

    Development of Scenarios by Sandia National Laboratories (SNL)

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11. Response by (name):

12. Response date:

13. Response:

MGDS Annotated Outline Information Need Form
Form A: Information Request

Date: 5/28/93

1. Log number: **INN 6.3-002**

2. Section no. & title: **6.3 ASSESSMENT OF COMPLIANCE: CUMULATIVE RELEASE OF RADIOACTIVE MATERIALS**

3. Lead author & phone no: **Jim Duguid (703) 204-8851**

4. Information request date: **07/24/92**

5. Work location: **Vienna, Virginia**

6. Type of information needed:

   Documentation of the second iteration of total System Performance Assessment.

7. What is the information needed for?

   To modify Section 6.3 and update Chapter 6 in general.

8. What group is the probable information supplier?

   Performance Assessment, Bob Andrews

9. When is the information needed?

   December 1993

10. What kind of related information is already available in references, etc.? (List any known, related information sources):

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11. Response by (name):

12. Response date:

13. Response:

MGDS Annotated Outline Information Need Form

Date: 5/28/93

Form A: Information Request

1. Log number: **INN 6.3-003**

2. Section no. & title: **6.3 ASSESSMENT OF COMPLIANCE: CUMULATIVE RELEASE OF RADIOACTIVE MATERIALS**

3. Lead author & phone no: **Jim Duguid (703) 204-8851**

4. Information request date: **02/03/93**

5. Work location: **Vienna, Virginia**

6. Type of information needed:

   The EPA standard for the Yucca Mountain site.

7. What is the information needed for?

   To provide release/dose requirements for the high-level waste repository at Yucca Mountain. Currently 40 CFR 191 is being used until new standards are available.

8. What group is the probable information supplier?

   The Environmental Protection Agency.

9. When is the information needed?

   1995

10. What kind of related information is already available in references, etc.?

    40 CFR 191

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11. Response by (name):

12. Response date:

13. Response:

MGDS Annotated Outline Information Need Form
Form A: Information Request

Date: 5/28/93

1. Log number: **INN 6.3-004**

2. Section no. & title: **6.3 ASSESSMENT OF COMPLIANCE: CUMULATIVE RELEASE OF RADIOACTIVE MATERIALS**

3. Lead author & phone no: **Jim Duguid (703) 204-8851**

4. Information request date: **02/03/93**

5. Work location: **Vienna, Virginia**

6. Type of information needed:

   Processes and events retained and a discussion of their effects on the performance assessment results.

7. What is the information needed for?

   For completion of Table 6.3B and related text.

8. What group is the probable information supplier?

   Performance Assessment

9. When is the information needed?

   December 1993

10. What kind of related information is already available in references, etc.?

    First iteration of PA conducted by SNL.

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11. Response by (name):

12. Response date:

13. Response:

MGDS Annotated Outline Information Need Form

Date: 5/28/93

Form A: Information Request

1. Log number: **INN 6.3-005**

2. Section no. & title: **6.3 ASSESSMENT OF COMPLIANCE: CUMULATIVE RELEASE OF RADIOACTIVE MATERIALS**

3. Lead author & phone no: **Jim Duguid (703) 204-8851**

4. Information request date: **02/03/93**

5. Work location: **Vienna, Virginia**

6. Type of information needed:

   Methods used to eliminate insignificant processes and events, processes and events that were eliminated, and the justification for elimination of each.

7. What is the information needed for?

   For completion of Table 6.3C and related text.

8. What group is the probable information supplier?

   Performance Assessment

9. When is the information needed?

   December 1994

10. What kind of related information is already available in references, etc.?

    Development of scenarios by SNL.

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11. Response by (name):

12. Response date:

13. Response:

MGDS Annotated Outline Information Need Form
Form A: Information Request

Date: 5/28/93

1. Log number: **INN 6.3-006**

2. Section no. & title: **6.3 ASSESSMENT OF COMPLIANCE: CUMULATIVE RELEASE OF RADIOACTIVE MATERIALS**

3. Lead author & phone no: **Jim Duguid (703) 204-8851**

4. Information request date: **02/03/93**

5. Work location: **Vienna, Virginia**

6. Type of information needed:

   Method of combination of processes and events into scenarios.

7. What is the information needed for?

   For completion of Figure 6.3A and related text.

8. What group is the probable information supplier?

   Performance Assessment

9. When is the information needed?

   December 1994

10. What kind of related information is already available in references, etc.?

    Development of scenarios by SNL.

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11. Response by (name):

12. Response date:

13. Response:

MGDS Annotated Outline Information Need Form

Date: 5/28/93

Form A: Information Request

1. Log number: **INN 6.3-007**

2. Section no. & title: **6.3 ASSESSMENT OF COMPLIANCE: CUMULATIVE RELEASE OF RADIOACTIVE MATERIALS**

3. Lead author & phone no: **Jim Duguid (703) 204-8851**

4. Information request date: **02/03/93**

5. Work location: **Vienna, Virginia**

6. Type of information needed:

   Criteria used for screening scenarios.

7. What is the information needed for?

   For completion of Table 6.3D and related text.

8. What group is the probable information supplier?

   Performance Assessment

9. When is the information needed?

   December 1994

10. What kind of related information is already available in references, etc.?

    Development of scenarios by SNL.

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11. Response by (name):

12. Response date:

13. Response:

MGDS Annotated Outline Information Need Form
Form A: Information Request

Date: 5/28/93

1. Log number: **INN 6.3-008**

2. Section no. & title: **6.3 ASSESSMENT OF COMPLIANCE: CUMULATIVE RELEASE OF RADIOACTIVE MATERIALS**

3. Lead author & phone no: **Jim Duguid (703) 204-8851**

4. Information request date: **02/03/93**

5. Work location: **Vienna, Virginia**

6. Type of information needed:

   The level of confidence necessary for screening the scenarios (i.e., to determine whether or not a scenario was retained).

7. What is the information needed for?

   For completion of Table 6.3E and related text.

8. What group is the probable information supplier?

   Performance Assessment

9. When is the information needed?

   December 1994

10. What kind of related information is already available in references, etc.?

    Development of scenarios by SNL.

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11. Response by (name):

12. Response date:

13. Response:

MGDS Annotated Outline Information Need Form Date: 5/28/93
Form A: Information Request

1. Log number: **INN 6.3-009**

2. Section no. & title: **6.3 ASSESSMENT OF COMPLIANCE: CUMULATIVE RELEASE OF RADIOACTIVE MATERIALS**

3. Lead author & phone no: **Jim Duguid (703) 204-8851**

4. Information request date: **02/03/93**

5. Work location: **Vienna, Virginia**

6. Type of information needed:

   The results of the scenario screening along with the results of their analyses.

7. What is the information needed for?

   For completion of Table 6.3F and Figures 6.3B through 6.3Bn and related text.

8. What group is the probable information supplier?

   Performance Assessment

9. When is the information needed?

   December 1995

10. What kind of related information is already available in references, etc.?

    Second and third iteration of PA.

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11. Response by (name):

12. Response date:

13. Response:

MGDS Annotated Outline Information Need Form
Form A: Information Request

Date: 5/28/93

1. Log number: **INN 6.3-010**

2. Section no. & title: **6.3 ASSESSMENT OF COMPLIANCE: CUMULATIVE RELEASE OF RADIOACTIVE MATERIALS**

3. Lead author & phone no: **Jim Duguid (703) 204-8851**

4. Information request date: **02/03/93**

5. Work location: **Vienna, Virginia**

6. Type of information needed:

   Discussion of methods used in analyses of scenarios, repository under expected conditions, and CCDFs of the results.

7. What is the information needed for?

   For completion of Table 6.3G and Figures 6.3B through 6.3Bn and related text.

8. What group is the probable information supplier?

   Performance Assessment

9. When is the information needed?

   December 1994

10. What kind of related information is already available in references, etc.?

    First and second iteration of PA.

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11. Response by (name):

12. Response date:

13. Response:

MGDS Annotated Outline Information Need Form Date: 5/28/93
Form A: Information Request

1. Log number: **INN 6.3-011**

2. Section no. & title: **6.3 ASSESSMENT OF COMPLIANCE: CUMULATIVE RELEASE OF RADIOACTIVE MATERIALS**

3. Lead author & phone no: **Jim Duguid (703) 204-8851**

4. Information request date: **02/03/93**

5. Work location: **Vienna, Virginia**

6. Type of information needed:

Probabilities of occurrence of processes and events along with the uncertainty in their determination.

7. What is the information needed for?

For completion of Table 6.3H and related text.

8. What group is the probable information supplier?

Performance Assessment

9. When is the information needed?

December 1994

10. What kind of related information is already available in references, etc.?

Development of scenarios by SNL.

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11. Response by (name):

12. Response date:

13. Response:

The above Annotated Outline text is guidance that may be used for the future development of an MGDS facility License Application.

MGDS Annotated Outline Information Need Form
Form A: Information Request

Date: 5/28/93

1. Log number: **INN 6.3-012**

2. Section no. & title: **6.3 ASSESSMENT OF COMPLIANCE: CUMULATIVE RELEASE OF RADIOACTIVE MATERIALS**

3. Lead author & phone no: **Jim Duguid (703) 204-8851**

4. Information request date: **02/03/93**

5. Work location: **Vienna, Virginia**

6. Type of information needed:

   Probabilities of occurrence of scenarios and processes and events along with the uncertainty in their determination.

7. What is the information needed for?

   For completion of Table 6.3I, 6.3J, and 6.3K and related text.

8. What group is the probable information supplier?

   Performance Assessment

9. When is the information needed?

   December 1994

10. What kind of related information is already available in references, etc.?

    Development of scenarios by SNL.

---

11. Response by (name):

12. Response date:

13. Response:

MGDS Annotated Outline Information Need Form

Date: 5/28/93

Form A: Information Request

1. Log number: **INN 6.3-013**

2. Section no. & title: **6.3 ASSESSMENT OF COMPLIANCE: CUMULATIVE RELEASE OF RADIOACTIVE MATERIALS**

3. Lead author & phone no: **Jim Duguid (703) 204-8851**

4. Information request date: **02/03/93**

5. Work location: **Vienna, Virginia**

6. Type of information needed:

   Methods of formation of CCDFs and related uncertainty and sensitivity analyses.

7. What is the information needed for?

   For completion of Figures 6.3B (there is one Figure for each of n scenarios), and related text.

8. What group is the probable information supplier?

   Performance Assessment

9. When is the information needed?

   December 1995

10. What kind of related information is already available in references, etc.?

    Second iteration of PA.

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11. Response by (name):

12. Response date:

13. Response:

MGDS Annotated Outline Information Need Form
Form A: Information Request

Date: 5/28/93

1. Log number: **INN 6.3-014**

2. Section no. & title: **6.3 ASSESSMENT OF COMPLIANCE: CUMULATIVE RELEASE OF RADIOACTIVE MATERIALS**

3. Lead author & phone no: **Jim Duguid (703) 204-8851**

4. Information request date: **02/03/93**

5. Work location: **Vienna, Virginia**

6. Type of information needed:

   Demonstration of site suitability and related analyses.

7. What is the information needed for?

   For completion of Section 6.3.5.1.

8. What group is the probable information supplier?

   Performance Assessment

9. When is the information needed?

   December 1995

10. What kind of related information is already available in references, etc.?

    Second iteration of PA and Early Site Suitability Evaluation (ESSE) document.

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11. Response by (name):

12. Response date:

13. Response:

MGDS Annotated Outline Information Need Form
Form A: Information Request

Date: 5/28/93

1. Log number: **INN 6.3-015**

2. Section no. & title: **6.3 ASSESSMENT OF COMPLIANCE: CUMULATIVE RELEASE OF RADIOACTIVE MATERIALS**

3. Lead author & phone no: **Jim Duguid (703) 204-8851**

4. Information request date: **02/03/93**

5. Work location: **Vienna, Virginia**

6. Type of information needed:

   Discussion of the methods of production of the CCDF, uncertainties in its production, and alternative representations of CCDFs.

7. What is the information needed for?

   For completion of Tables 6.3L, Table 6.3M, Figure 6.3C, and related text.

8. What group is the probable information supplier?

   Performance Assessment

9. When is the information needed?

   December 1995

10. What kind of related information is already available in references, etc.?

    First and second iterations of PA.

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11. Response by (name):

12. Response date:

13. Response:

MGDS Annotated Outline Information Need Form
Form A: Information Request

Date: 5/28/93

1. Log number: **INN 6.3-016**

2. Section no. & title: **6.3 ASSESSMENT OF COMPLIANCE: CUMULATIVE RELEASE OF RADIOACTIVE MATERIALS**

3. Lead author & phone no: **Jim Duguid (703) 204-8851**

4. Information request date: **02/03/93**

5. Work location: **Vienna, Virginia**

6. Type of information needed:

   Discussion of verification and validation of all models and codes used for performance assessment including their QA documentation.

7. What is the information needed for?

   For completion of Tables 6.3N and related text.

8. What group is the probable information supplier?

   Performance Assessment

9. When is the information needed?

   December 1995

10. What kind of related information is already available in references, etc.?

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11. Response by (name):

12. Response date:

13. Response: