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

April 17, 1991

Volume II of II

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

Volume Two

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Chapter 5.0 Engineered Barrier Systems

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5.0 ENGINEERED BARRIER SYSTEMS

Skeleton Text Has Not Been Developed For This Section.

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REFERENCES

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MGDS Annotated Outline Planning Package
Form 1: Text

Date: 4/17/92

1. Section No. & Title: **5.0 ENGINEERED BARRIER SYSTEMS**

2. Lead Author & Phone No. Hugh Benton 702-794-1891

3. First Phase Planning Package Due: 6/21/91

   Second Phase Planning Package Due: 10/18/91

   First Phase Skeleton Draft Due: 12/30/91

   Second Phase Skeleton Draft Due: 3/15/92

4. Plan Approved: W.R. Griffin 8/27/91
   (Licensing Mgr & Lead Author)

5. Section Summary (Approximately 100 Words):

   The description and evaluation of the engineered barrier systems (EBS) includes a discussion of the overall purpose and function of the EBS and how the EBS fulfills the requirements of 10 CFR 60.

6. Opening Statement: None.

7. Main Body Outline:

   - EBS purpose, function, description and evaluation (Reference 5.1)
   - How the EBS fulfills 10 CFR 60 requirements (Reference 5.2).

8. Conclusion: See Item 5 (above) and Section 5.2.

9. Support Authors & Their Assignments:

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MGDS Annotated Outline Planning Package
Form 2: Figures & Tables

Date: 4/17/92

Section No. & Title:

Lead Author & Phone No.

A. Figure/Table No.

Caption/Title:

Content:

B. Figure/Table No.

Caption/Title:

Content:

C. Figure/Table No.

Caption/Title:

Content:

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MGDS Annotated Outline Planning Package
Form 3: References

Date: 4/17/92

Section No. & Title:

Lead Author & Phone No.

Instructions: List all books, articles, or other references that are expected to be used for the section. Indicate whether references are draft or final and whether they are publicly available (i.e., published). Refer to the Writer's Guide, Appendix D of the Annotated Outline Management Plan for guidance on formatting reference information.

1.

2.

3.

4.

5.

6.

7.

8.

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MGDS Annotated Outline Information Need Form
Form A: Information Request

Date: 4/17/92

1. Log number:

2. Section no. & title: **5.0 ENGINEERED BARRIER SYSTEMS**

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

4. Information request date:

5. Work location:

6. Type of information needed:

7. What is the information needed for?

8. What group is the probable information supplier?

9. When is the information needed?

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 B: Information Response

Date: 4/17/92

1. Section No. & Title:

2. Person Supplying Information:

3. Phone No.:

4. Lead Author (Requester): Hugh Benton (702) 794-1891

   Instructions: Information suppliers may use this form to communicate information that has been requested by lead authors via Information Request Forms. The Log No. on this form should be identical to the Log No. of the Information Request Form.

5. Response by Information Supplier:

Note: Attach additional sheets if necessary.

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MGDS Annotated Outline Information Need Form
Form C: Information Request Tracking Log

Date: 4/17/92

Note: This is a recommended format for a manual tracking system. Other tracking methods such as a simple computer data base are also acceptable.

Date:

Lead Author:

Log No.	Section	Date Issued	Date Response Received

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5.1 DESCRIPTION OF THE ENGINEERED BARRIER SYSTEMS

5.1.1 Waste Package Design Description

5.1.1.1 Waste Package Design

5.1.1.2 Alternative Design

5.1.1.3 Comparative Evaluation of Alternative Waste Package Designs

The comparative evaluation of waste package designs involves the complete list of performance requirements including:

- Fabricability
- Handling
- Closure
- Inspection
- Emplacement
- Retrievability
- Criticality
- Containment
- Isolation
- Reliability
- Performance confirmation.

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The evaluation of substantially complete containment (SCC) (Issue 1.4) and radionuclide release from the EBS (Issue 1.5) are evaluated by performance assessment (PA). Details of the approach can be found in Sections 5.2.2.1 and 5.2.2.2, respectively. Briefly, PAs are performed to determine whether the reference and alternative designs meet the requirements of SCC and release as defined in 10 CFR 60.113. The parameter values given in the SCP are compared with those generated as a result of the test program. The testing program includes all the identified degradation modes, and the assessments include a range of environmental scenarios. This permits the calculation of the number of early failures, the number of failures during the containment period, and the release of radionuclides from the EBS. The margin of uncertainty was also evaluated.

The results are compared to the performance objectives for SCC and release to determine that they have been met with sufficient confidence such that the NRC can make a finding of reasonable assurance, that radioactive materials can be disposed in the repository without unreasonable risk to the health and safety of the public.

The final reference and alternative designs will meet the NRC requirements with sufficient margin. The selection of the license application design will depend on other factors such as cost of the entire waste package container fabrication and emplacement system, the maturity of the technology, and hence the schedule its use would require, the degree of risk entailed with the option, and other technical or programmatic considerations.

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5.1.2 Waste Forms Characteristics and Acceptance

Waste forms to be received and packaged for disposal will include both unreprocessed spent fuel from commercial power reactors, and canisters of solidified high-level wastes from commercial and defense fuel reprocessing operations. These waste forms are specified in the DOE Code of Federal Regulation, 10CFR 961 (Reference). The commercial high-level waste will be received from the West Valley Demonstration Project in New York (WVDP). High-level wastes from the defense program activities at Savannah River, Hanford, and Idaho may also be disposed of in the repository. Characteristics of the waste from the Defense Waste Processing Facility (DWPF) at the Savannah River Plant have been established. Development of defense high-level waste acceptance documentation is governed by a Memorandum of Agreement (MOA) between DOE/EM and DOE/RW (Reference). Definitive information is not yet available for defense wastes from the Hanford and Idaho sites.

5.1.2.1 Waste Forms Descriptions and Sources

Spent Fuel. Spent fuel is enriched uranium oxide, transuranic nuclides, and fission and activation products resulting from operation of commercial light water power reactors (LWR) and the zirconium alloy or stainless steel cladding, which also contains activation products. Intact spent fuel assemblies include many other metallic components, such as end fittings, flow channels, guide tubes, springs, and spacer grids, each of which contain activation products.

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Standard spent fuel is defined in 10 CFR Part 961, the Standard Contract for Disposal of Spent Nuclear Fuel and/or High-Level Radioactive Wastes, as nuclear fuel with a minimum age of 5 years after discharge from the reactor.

The burnup of LWR fuel is expressed as the fission (thermal) energy released per unit of initial uranium weight loaded into a reactor core. A commonly used unit is megawatt-days per metric ton uranium (MWd/MTU). The build-up of fission products in the fuel is proportional to the energy generated in the reactor. These fission products, and the actinides formed by neutron capture reactions, are the principal sources of radioactivity in spent fuel. Thus the spent fuel burnup, together with the fuel age, determines the radionuclide inventory. Radioactive decay of this inventory produces the thermal energy that must be dissipated in the repository.

Fuel in pressurized water reactor (PWR) and boiling water reactor (BWR) assemblies is presently enriched to approximately 3.2 and 2.6 weight percent fissile U-235, respectively, and is irradiated to achieve burnups of about 33,000 and 27,500 MWd/MTU. As nuclear power plants have matured, the average burnup of spent fuel assemblies has increased toward these values. The evolving economics of the nuclear power industry has produced an incentive to increase enrichments to allow higher burnups. A recent survey of fuel vendors indicated that approximately two-thirds of the present U.S. nuclear power plants have made commitments toward the purchase of fuels with higher enrichments to allow longer fuel residence times in reactor cores, that will result in higher burnups.

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For an industry-predicted average PWR fuel burnup of 35,000 MWd/MTU in 2020, a number of cases in excess of the average would occur. If a PWR plant were to discharge a batch of fuel with an average burnup of 42,000 MWd/MTU, a small number of assemblies would be expected to be as high as 60,000 MWd/MTU.

High-Level Waste Glass. High-level radioactive wastes from the DWPF at Savannah River and the West Valley Demonstration Project (WVDP) will be received in solidified form. The radionuclides will be immobilized in a borosilicate glass matrix contained in 304L stainless steel pour canisters. Because of concerns that thermal cycles associated with the glass pouring operation will result in the pour canisters being highly stressed, pour canisters will not be used as the primary barrier to meet the containment performance objective.

5.1.2.2 Quantity of HLW to be Emplaced

Spent Fuel. A summary of the quantities of spent fuel expected to be received at the repository is shown in Table 5.1A **[HB1]**. After the repository startup phase, a receipt rate of 3,000 MTU per year is anticipated. The spent fuel will be packaged and emplaced as soon as possible after receipt. Table 5.1B **[HB2]** gives a tabulation of the anticipated burnup distribution and age at repository receipt of spent fuel as a function of time from 2010 to 2032.

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Table 5.1A. Summary Quantity of Spent Fuel Receipt at Repository

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Table 5.1B. Anticipated Burn-up Distribution/Age at Repository/2010-2032

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Table 5.1C. Summary of HLW Glass Receipt at Repository

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High-Level Waste Glass. Delivery of high-level waste glass to the repository is scheduled to begin approximately 5-6 years after repository start-up. A summary of the quantities of HLW Glass expected to be received at the repository is given in Table 5.1C **[HB3]**. The HLW glass canisters will be packaged and emplaced as soon as possible after receipt. After the repository startup phase, a receipt rate of 400MTU/yr or 800 glass canisters per year is anticipated.

5.1.2.3 Waste Form Characteristics

Spent Fuel. Table 5.1D **[HB-4]** presents typical chemical, thermal, and radiological characteristics of 5, 10, 15 and 20 year old spent fuel to be received at the repository. There is a wide variation of PWR and BWR fuel rod and fuel assembly dimensions, and these limits are depicted in Table 5.1E **[HB-5]**.

High-Level Waste Glass. Table 5.1F **[HB-6]** presents typical characteristics of DWPF HLW glass to be received at the repository. The pour canisters are 61 cm in diameter, 3.0 m long and nominally 1 cm thick 304L stainless steel, and are essentially identical for both WVDP and DWPF glass.

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Table 5.1D. Characteristics of 5 and 10 Year Old Spent Fuel at Repository

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Table 5.1E. Variation Between PWR/BWR Fuel Rod and Assembly Dimensions

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Table 5.1F. Typical DWPF HLW Glass Characteristics at Repository

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5.1.2.4 Waste Form Acceptance and Handling

Spent Fuel. Spent fuel may be received at the repository either as intact assemblies or canisters of fuel rods that may or may not have been consolidated at the reactors or other facilities. Intact assemblies include many other metallic components such as end fittings, flow channels, guide tubes, springs, and spacer grids. These non-fuel hardware components will also be packaged for repository disposal. The standard contract specifies that the oldest fuel will have the highest priority ranking for acceptance by DOE. During the early years of the repository receiving and emplacement period, the average spent fuel age will be greater than 10 years. This average age will steadily decline and will be reduced to the five year minimum during the last several years of operation. The waste package and repository designs must be capable of receiving and disposing standard spent fuel on a routine basis. Fuel cooled less than five years will remain in the storage system.

The utilities with the oldest spent fuel will be given the highest priority rankings for delivery of fuel to DOE. The utilities will then recommend whatever fuel they want for delivery, subject to DOE approval. This could be fuel of high burnup, freshly discharged. It could mean that the utilities recommend later delivery of their spent fuel in dry storage. The implication is that the repository may be in a position of receiving older, lower burnup spent fuel during the later years of operation.

Spent fuel may be received at the repository in at least three forms. The majority will be in the form of intact assemblies that contain undamaged fuel rods. Some of these fuel rods may have

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minor cladding breach defects, but would not be structurally damaged to the extent that the fuel is not safely contained. The second form is fuel that has been preconsolidated by being disassembled at the reactors or other facilities, with the rods packaged in canisters whose dimensions approximate those of an intact assembly. The reference consolidation factor is 2:1 (i.e., a canister contains the fuel rods from two fuel assemblies). No reference form for the configuration of nonfuel hardware resulting from these preconsolidation operations has been established. Hence, no provisions have been made for this material in the conceptual designs for either the waste package or repository surface facilities. The third form in which spent fuel is expected to be received is "failed fuel" that has been structurally damaged to the extent that the fuel assemblies must be placed in a canister to contain the particulate fuel materials during handling and shipment from the reactor. The 10 CFR 961 requires that "non-standard" spent nuclear fuel be treated as "failed fuel". No reference dimensions have been established for this category, but it is assumed that the canisters will be only slightly larger than the assemblies they contain.

The reference form for disposal of spent fuel is fuel rods that are removed from intact assemblies and consolidated at the repository. The option of disposing of intact spent fuel assemblies as they are received is retained in the reference design because it may not be possible to consolidate assemblies that are received at the repository in a damaged or failed condition. In addition, current planning envisages loading fuel with very high burnup and short cooling times into containers as intact assemblies in quantities dictated by the waste form temperature limitations.

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5.1.3 Underground Facility Design Description

5.1.4 Engineered Barrier System Emplacement Environment

[Characterization of the engineered barrier system environment, after waste emplacement, must be developed to help demonstrate compliance with PA goals and to provide the information necessary to carry out materials and design tests.] The following subsections describe the Yucca Mountain site conditions as they exist now at the potential waste emplacement horizon and as they would be modified as a result of waste package emplacement.

Pre-Emplacement Site Conditions. The Yucca Mountain Site Characterization Project has selected the Topopah Spring Member of the Paintbrush Tuff as the recommended repository horizon for a potential repository of high-level nuclear waste at Yucca Mountain. The investigations that led to this selection are discussed in the unit evaluation report (Johnstone et al, 1984). The recommended horizon is the welded, devitrified section of Topopah Spring tuff that lies above the basal vitrophyre of the unit. The choice of the unsaturated zone as the location for the reference repository horizon marks a departure from the conventional environment that has been considered for repository siting. The pre-emplacement site conditions are discussed in detail in Section 3.1 of this License Application, Description of Individual Systems and Characteristics of the Site.

Post-Emplacement Environment. Construction of a repository and the emplacement of heat and radiation generating waste in the repository would cause changes in the physical and

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chemical characteristics of the environment. [A thorough understanding of the changes in the environment that would occur with time as affected by the repository construction and waste emplacement needs to be developed.] The effects that can be expected from development of the repository and emplacement of the waste packages are: 1) physical changes in the rock unit due to mining activities, 2) changes in the physical and chemical properties of the rock and vadose water due to the waste-related radiation field, 3) changes in the chemical properties of the water due to manmade materials, 4) heat-induced mechanical effects, 5) modification of moisture conditions due to mining ventilation, and 6) modification of the ambient rock/water system, and hydrodynamic regime due to the thermal load generated by the waste packages.

Stability of Emplacement Openings. Stability of emplacement openings is of concern during construction, after emplacement, but before closure when the option to retrieve the waste package must be maintained; and for the 1,000 year period after closure when substantially complete containment must be achieved.

[Emplacement opening thermomechanical analyses must be conducted to establish the potential for loading of waste packages.] Loading of packages due to thermomechanical forces could result from either failure of intact rock (matrix) or by movement of rocks along preexisting discontinuity planes. The analyses show that _____.

The primary effect of temperature changes on the near field rock will be a change in rock volume due to isobaric thermal expansion. Except for quartz and cristobalite, the isobaric thermal expansion of most silicate minerals, on average, is 3x10-5/K (Helgeson et al, 1978). The

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maximum rock temperature attained by the near field environment, based on the analyses described below, results in a total volume change of about _____ percent using the average thermal expansion value.

Cristobalite, which is present in the near field rock, undergoes a structural transition from tetragonal (alpha-cristobalite) to cubic (beta-cristobalite) symmetry. This phase transition results in a volume increase of about five percent (Helgeson et al., 1978). The temperature at which this phase transition occurs has been measured for naturally occurring cristobalite at Yucca Mountain (Wolfsberg and Vaniman, 1984), and has been found to be 225 +/- 25 C.

The alpha-to-beta cristobalite transition temperature falls within the temperature range expected for the very near field rock. The effect of the associated volume change on waste package loading is _____.

Anticipated Thermal History and Effects. The waste package design will accommodate a thermal loading of _____ for spent fuel and will generate _____ when loaded with processed high-level waste in the form of borosilicate glass. Figure 5.1A shows a typical thermal history for the reference spent fuel waste package and its immediate surroundings. For an unventilated emplacement drift, the rock at the emplacement opening would reach a maximum temperature of _____ at ____ years after package emplacement. Due to edge effects, waste package environments along the perimeter of a repository will have a thermal history different from that depicted in Figure 5.1A.

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Figure 5.1A. Typical Thermal History - Spent Fuel Waste Package and Surroundings

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At the elevation of the repository horizon, the unconfined boiling point of pure water is approximately 96C. Differences in flow paths and residence time have contributed to varying pore water compositions at Yucca Mountain. Although concentration of the solute species will occur during boiling and evaporation, elevation of the boiling point is less than 1C (DePoorter, 1986; Montana, 1986), for solutions that are as much as 100 times more concentrated than the reference ground waters (Wells J-13, H-3, P-1, and Yang's pore water extracts). Expected geochemical reaction paths during evaporation, boiling, and condensation of reference waters have been determined by _____ to assess their corrosive potential, and to determine limiting solubilities of waste components. It has been shown that _____.

Vaporization of unconfined and unbound pore fluid can therefore be assumed to be complete at approximately 97C. This phenomenon will result in the development of a dehydration zone around the waste package, the width and duration of which will depend on the migration behavior of the boiling point isotherm. The thermal profile history presented in Figure 5.1.4-1 suggests that the rock will be at temperatures in excess of the boiling point, and therefore dehydrated, for at least _____ years. The effect of large scale heterogeneities that could provide liquid pathways from zones of fluid accumulation back to the repository have been evaluated, and _____. The role of such heterogeneities as gas pathways has been shown to be _____.

Radiation Field Effects. The types of ionizing radiation that interact with the rock/water/vapor system will be neutron and gamma radiation; alpha and beta radiation will not penetrate the intact waste container. The absorbed dose from gamma radiation will dominate over that from

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neutron radiation by more than four orders of magnitude (Van Konynenburg, 1984). The total radiation field at the container outer surface will be less than _____ rads/hour. The gamma radiation is expected to result in negligible damage to silicate rock (Durham et al., 1985). Less than three percent of the total thermal energy released by the waste package will be deposited in the host rock by gamma radiation (Van Konynenburg, 1984).

The waste package has been designed to prevent significant gamma radiolysis effects on the environment at the outer surface of the containment barrier(s). [Experimental and numerical analysis work must be performed to demonstrate that the gamma radiolysis effects will be negligible.] This work shows that _____.

Water Flow in the Vicinity of Waste Packages. [Modeling of the effect of the thermal perturbation on local hydrologic transport must demonstrate that _____. [Experimental studies and numerical analyses must be conducted to determine the extent to which liquid-vapor cycling phenomena will occur in a natural system, and the effect of this behavior on near field water chemistry.] It has been shown that _____.

Water transport within the repository horizon occurs by a combination of vapor transport, water migration through the matrix, and fracture flow (Montazer and Wilson, 1984). The relative importance of each flow mechanism is a function of the bulk saturation, flux of water through the rock, temperature gradients, fracture network characteristics, and matrix permeability. [It has been established that the fracture density within this lower nonlithophysal zone varies between

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____ and ____ fractures per cubic meter, with a mean matrix porosity of ____ percent and a mean saturation of ____ percent.]

[The net flux of water through the repository has been determined to be _____ mm/year in the upward direction, although a downward flux of _____ to _____ mm/year occurs as matrix flow and _____ to _____ mm/year as fracture flow. The current matric potential of the Topapah Spring tuff is approximately _____ kPa which results in negliglible fracture flow except during episodic "flooding" events. This conclusion is based on the assumption of a fracture-matrix equilibrium, that has been shown to exist except _____.]

[Because water enhances the corrosion of metal barriers and is the main agent for the transport of radionuclides, experimental and numerical modeling studies must be conducted to characterize fluid flow and the geochemistry of water/rock interactions in the Topopah Spring tuff. The effects of manmade materials on the ground water chemistry have been determined also.] These studies have shown that _____.

5.1.5 Underground Operations Radiation Protection

5.1.5.1 Direct Exposure

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5.1.5.2 Effluent Release and Contamination

Post-closure releases from the EBS and the total system that could impact individuals outside of the accessible environment are evaluated as part of the PA activity. The evaluation requires the development and utilization of a total system performance code as described in Section 6.3.6. The resulting radionuclide exposures were found to be a small fraction of the requirements in 40 CFR Part 191 (assuming that this regulation has been repromulgated).

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5.1F Van Konynenburg, R. A., 1984. Radiation Doses in Granite Around Emplacement Holes in the Spent Fuel Test -- Climax (Final Report), UCRL-53580, Lawrence Livermore National Laboratory, Livermore, Calif.

5.1G Durham, W. B., J. M. Beiriger, M. Axelrod, and S. Trettenero, 1985. The Effect of Gamma Irradiation on the Strength and Elasticity of Climax Stock and Westerly Granites, UCRL-92526, preprint, Lawrence Livermore National Laboratory, Livermore, Calif.

5.1H Montazer, P., and W. E. Wilson, 1984. Conceptual Hydrologic Model of Flow in the Unsaturated Zone, Yucca Mountain, Nevada, USGS-WRI-84-4345, Water-Resources Investigations Report, U.S. Geological Survey.

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

MGDS Annotated Outline Planning Package
Form 1: Text

Date: 4/17/92

1. Section No. & Title: **5.1 DESCRIPTION OF THE ENGINEERED BARRIER SYSTEMS**

2. Lead Author & Phone No. Hugh Benton 702-794-1891

3. First Phase Planning Package Due: 6/21/91

   Second Phase Planning Package Due: 10/18/91

   First Phase Skeleton Draft Due: 12/30/91

   Second Phase Skeleton Draft Due: 3/15/92

4. Plan Approved: W.R. Griffin 8/27/91
   (Licensing Mgr & Lead Author)

5. Section Summary (Approximately 100 Words):

   This section provides a description of the EBS and components as well as their intended functions and relations in the overall repository design. The section identifies structures, systems, and components of the EBS, and it indicates whether or not they have been classified as important to safety, retrievability, or isolation.

6. Opening Statement:

   The EBS consists of multiple barriers that will ensure isolation of the high-level nuclear waste in accordance with applicable federal regulatory requirements.

7. Main Body Outline: See attached.

8. Conclusion:

   See Section 5.2, Item 8.

9. Support Authors & Their Assignments:

   Paul McKie, Underground Facility (5.1.3)
   Tom Statton (5.1.4, Pre-emplacement portion)
   M. Foitsch (5.1.5)

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

7. Main Body Outline (Continued)

5.1 DESCRIPTION OF THE ENGINEERED BARRIER SYSTEMS

5.1.1 Waste Package Design Description

5.1.1.1 Waste Package Design

- Waste Package Component Descriptions

  - Waste Form
  - Filler/structural framework
  - Shielding
  - Containers (include any coatings)
  - Packing/Absorbent Materials
  - Liners
  - Material specification and any applicable manufacturing details; functions and performance allocation will be included with description of respective components.

  [Note that closure/seals are not separated, but are included with each component as appropriate.]

- Waste Package Fabrication/Assembly Description

5.1.1.2 Alternative Design

Same outline as above.

5.1.1.3 Comparative Evaluation of Alternative Waste Package Designs

- Evaluations of substantially complete containment (Issue 1.4)
- Evaluations of effect on radionuclide release from EBS (Issue 1.5)
- Cost and schedule evaluations.

5.1.2 Waste Form Characteristics And Acceptance

[Cross reference to other discussions of the same subject. If they are not responsive to the FCRG, then use the outline below.]

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

7. Main Body Outline (Continued)

5.1.2.1 Waste Forms Descriptions and Sources

- Spent Fuel
- Glass HLW.

5.1.2.2 Quantity of HLW to be Emplaced

- Spent Fuel
- Glass HLW
- Emplacement Schedule.

5.1.2.3 Waste Form Characteristics

- Spent Fuel
  - Physical
  - Chemical.
  - Thermal
  - Radiological.
- Glass HLW
  - Physical
  - Chemical
  - Thermal
  - Radiological.

5.1.2.4 Waste Form Acceptance and Handling

Waste form acceptance procedures and activities are described. Any special waste form handling, consolidation and/or canisterization will be described.

5.1.3 Underground Facility Design Description

[Expect cross reference to 4.1.3.]

- General description
  - Waste Emplacement Areas
  - Panels

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

7. Main Body Outline (Continued)

- Emplacement drifts
- Boreholes.

- Descriptions of portions of the underground facility that are part of the EBS

  - Provisions for retrieval.

- Backfill materials

  - Particle size distributions
  - Physical and chemical characteristics with time, mechanical, thermal, and thermomechanical properties.

- Emplacement machinery
- Capability for retrieval or removal.

5.1.4 Engineered Barrier System Emplacement Environment

- Pre-emplacement site conditions

  - Ambient temperature
  - Mechanical, physical, and chemical properties of the host rock
  - Geology of the site.

    - Faultic information
    - Seismic information.

- Post-emplacement environment

  - Changes in emplacement environment caused by construction of the repository and emplacement of wastes surrounded by backfill
  - Expected post closure temperature profile with time of the backfill or packing around waste packages
  - Characteristics of the ground water at the outermost boundary of the waste package compared with that of the interface of the backfill or packing and the next package component.

5.1.5 Underground Operations Radiation Protection

[Cross reference as appropriate to Chapter 4.]

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

7. Main Body Outline (Continued)

5.1.5.1 Direct Exposure

- Remote handling - description of system for
- Biological shielding - describe measures.

5.1.5.2 Effluent Release and Contamination

- Worker Safety Measures
  - Measures to be taken to maintain the radiological safety of workers in the underground facility during:
    - Handling
    - Storage
    - Retrieval
    - Emplacement
    - Isolation.
  - Address the above for:
    - Normal operations
    - Anticipated operation occurrences
    - Accident conditions
    - Evaluation of Radiation Exposure Potential to Workers.
  - Physical and chemical properties of any radioactive and hazardous effluent expected to be discharged into the underground facility as a result of any operational occurrences and accident conditions.
- Evaluation of Radiation Exposure Potential
  - Characteristics of any effluent that could be released from the underground facility that result in a projected radiation exposure to members of the public or to workers in the surface facility. For each effluent, this section provides an estimate of the dose to the public and to workers.

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

7. Main Body Outline (Continued)

5.1.5.3 Monitoring

- Detection - description of system for
- Remediation - measures for
- Records - maintenance and analysis of.

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

Section No. & Title: **5.1 DESCRIPTION OF THE ENGINEERED BARRIER SYSTEMS**

Lead Author & Phone No. Hugh Benton (702) 794-1891

A. Figure No. **5.1A**

Title: **Summary of Quantity of Spent Fuel Receipt at Repository**

Content: This table contains a summary of the quantities of spent fuel expected to be received at the repository.

B. Table No. **5.1B**

Title: **Anticipated Burn-up Distribution/Age at Repository/2010-2032**

Content: This table contains a tabulation of the anticipated burn-up distribution and age of spent fuel at the repository as a function of time between 2010 and 2032.

C. Table No. **5.1C**

Title: **Summaries of the Quantities of HLW Glass Expected to be Received at the Repository**

Content: This table provides a description of the quantities of HLW glass expected to be received at the repository.

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

Section No. & Title: **5.1 DESCRIPTION OF THE ENGINEERED BARRIER SYSTEMS**

Lead Author & Phone No. Hugh Benton (702) 794-1891

A. Table No. **5.1D**

Title: **Characteristics of 5 and 10 Year Old Spent Fuel at Repository**

Content: This table represents the typical characteristics of 5 and 10 year old spent fuel to be received at the repository.

	Characteristics			
Waste Form	Physical	Chemical	Thermal	Radiological

B. Table No. **5.1E**

Title: **Variation Between PWR/BWR Fuel Rod and Assembly Dimensions**

Content: This table presents PWR and BWR fuel rod and fuel assembly dimensional limits.

C. Table No. **5.1F**

Title: **Typical Characteristics of DWPF HLW Glass Received at the Repository**

Content: This table presents the typical characteristics of the DWPF HLW glass to be received at the repository.

	Characteristics			
Waste Form	Physical	Chemical	Thermal	Radiological

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

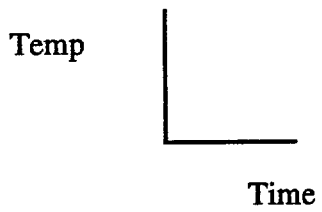
Section No. & Title: **5.1 DESCRIPTION OF THE ENGINEERED BARRIER SYSTEMS**

Lead Author & Phone No. Hugh Benton (702) 794-1891

A. Figure No. **5.1A**

Caption: **Typical Thermal History - Spent Fuel Waste Package and Surroundings**

Content: This figure depicts the temperature history of a typical reference spent fuel waste package, its components and the surrounding environment. The temperature will be plotted as a function of time for 10,000 years.



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

Section No. & Title: **5.1 DESCRIPTION OF THE ENGINEERED BARRIER SYSTEMS**

Lead Author & Phone No. Hugh Benton (702) 794-1891

Instructions: List all books, articles, or other references that are expected to be used for the section. Indicate whether references are draft or final and whether they are publicly available (i.e., published). Refer to the Writer's Guide, Appendix D of the Annotated Outline Management Plan for guidance on formatting reference information.

1. Johnstone, J. K., R. R. Peters, and P. F. Gnirk, 1984. Unit Evaluation at Yucca Mountain, Nevada Test Site: Summary Report and Recommendation, SAND83-0372, Sandia National Laboratories, Albuquerque, N. Mexico.

2. Helgeson, H. C., J. M. Delany, H. W. Nesbitt, and D. K. Bird, 1978. "Summary and Critique of the Thermodynamic Properties of Rock-Forming Mineral," American Journal of Science, Vol. 278-A, Kline Geology Laboratory, Yale University, New Haven, Conn.

3. Wolfsberg, K., and D. T. Vaniman, (Comps.), 1984. Research and Development Related to the Nevada Nuclear Waste Storage Investigations, October 1 -- December 31, 1983, LA-10032-PR, Los Alamos National Laboratory, Los Alamos, N. Mex.

4. DePoorter, G. L., 1986. Letter from G. L. DePoorter (LANL) to M. D. Valentine (DOE/NV), TWS-ES-NP/01-86-28, January 17, 1986; regarding adjustment for correct mole fraction by dividing solute concentration by 55.5.

5. Montan, D. N., 1986. Memorandum from D. N. Montan (LLNL) to L. B. Ballou (LLNL), May 9, 1986; regarding the boiling point of water - theme and variations.

6. Van Konynenburg, R. A., 1984. Radiation Doses in Granite Around Emplacement Holes in the Spent Fuel Test -- Climax (Final Report), UCRL-53580, Lawrence Livermore National Laboratory, Livermore, Calif.

7. Durham, W. B., J. M. Beiriger, M. Axelrod, and S. Trettenero, 1985. The Effect of Gamma Irradiation on the Strength and Elasticity of Climax Stock and Westerly Granites, UCRL-92526, preprint, Lawrence Livermore National Laboratory, Livermore, Calif.

8. Montazer, P., and W. E. Wilson, 1984. Conceptual Hydrologic Model of Flow in the Unsaturated Zone, Yucca Mountain, Nevada, USGS-WRI-84-4345, Water-Resources Investigations Report, U.S. Geological Survey.

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

MGDS Annotated Outline Information Need Form
Form A: Information Request

Date: 4/17/92

1. Log number: **HB-1**

2. Section no. & title: **5.1 DESCRIPTION OF THE ENGINEERED BARRIER SYSTEMS**

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

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

5. Work location: **M&O - Las Vegas**

6. Type of information needed:

   Table summarizing the quantities of spent fuel to be received at the MGDS.

7. What is the information needed for?

   Preparation of quantity of HLW to be emplaced Section 5.1.2.2. This will be Table 5.1A.

8. What group is the probable information supplier?

   Systems Analysis Group.

9. When is the information needed?

   TBD.

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

    Oak Ridge is generally a good source of information on this. They have a data base and publications on this subject. ("Characteristics of Potential Repository Wastes," DOE/RW-0184-R1).

---

11. Response by (name):

12. Response date:

13. Response:

MGDS Annotated Outline Information Need Form
Form A: Information Request

Date: 4/17/92

1. Log number: **HB-2**

2. Section no. & title: **5.1 DESCRIPTION OF THE ENGINEERED BARRIER SYSTEMS**

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

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

5. Work location: **M&O - Las Vegas**

6. Type of information needed:

   Table showing anticipated burn-up distribution/age at repository from 2010 to 2032.

7. What is the information needed for?

   Preparation of quantity of HLW to be emplaced Section 5.1.2.2. This will be Table 5.1B.

8. What group is the probable information supplier?

   Systems Analysis Group.

9. When is the information needed?

   TBD.

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

    Oak Ridge is a good source. ("Characteristics of Potential Repository Wastes," DOE/RW-0184-R1). LLNL has also generated a report ("Waste Forms Characteristics Report," to be issued).

---

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 License Application.

MGDS Annotated Outline Information Need Form
Form A: Information Request

Date: 4/17/92

1. Log number: **HB-3**

2. Section no. & title: **5.1 DESCRIPTION OF THE ENGINEERED BARRIER SYSTEMS**

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

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

5. Work location: **M&O - Las Vegas**

6. Type of information needed:

   Table showing a summary of the quantities of HLW glass expected to be received at the repository.

7. What is the information needed for?

   Preparation of quantity of HLW to be emplaced Section 5.1.2.2. This will be Table 5.1C.

8. What group is the probable information supplier?

   Systems Analysis Group.

9. When is the information needed?

   TBD.

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

    DWPF and WVDP have issued reports ("Waste Form Qualification Report" for DWPF and WVDP, respectively).

---

11. Response by (name):

12. Response date:

13. Response:

MGDS Annotated Outline Information Need Form
Form A: Information Request

Date: 4/17/92

1. Log number: **HB-4**

2. Section no. & title: **5.1 DESCRIPTION OF THE ENGINEERED BARRIER SYSTEMS**

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

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

5. Work location: **M&O - Las Vegas**

6. Type of information needed:

   Table showing typical characteristics of 5, 10, 15 and 20 year old spent fuel to be received at the repository.

7. What is the information needed for?

   Preparation of Waste Form Characteristics, Section 5.1.2.3. This will be Figure 5.1D.

8. What group is the probable information supplier?

   Systems Analysis Group.

9. When is the information needed?

   TBD.

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

    Oak Ridge SF Data Base. ("Characteristics of Potential Repository Wastes," DOE/RW-0184-R1). LLNL has also generated a report ("Waste Forms Characteristics Report," to be issued).

---

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 License Application.

MGDS Annotated Outline Information Need Form
Form A: Information Request

Date: 4/17/92

1. Log number: **HB-5**

2. Section no. & title: **5.1 DESCRIPTION OF THE ENGINEERED BARRIER SYSTEMS**

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

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

5. Work location: **M&O - Las Vegas**

6. Type of information needed:

   Table showing variation between PWR/BWR fuel rod and assembly dimensions.

7. What is the information needed for?

   Preparation of Waste Form Characteristics, Section 5.1.2.3. This will be Figure 5.1E.

8. What group is the probable information supplier?

   Systems Analysis Group.

9. When is the information needed?

   TBD.

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

    Oak Ridge Data Base. ("Characteristics of Potential Repository Wastes," DOE/RW-0184-R1). LLNL has also generated a report ("Waste Forms Characteristics Report," to be issued).

---

11. Response by (name):

12. Response date:

13. Response:

MGDS Annotated Outline Information Need Form
Form A: Information Request

Date: 4/17/92

1. Log number: **HB-6**

2. Section no. & title: **5.1 DESCRIPTION OF THE ENGINEERED BARRIER SYSTEMS**

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

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

5. Work location: **M&O - Las Vegas**

6. Type of information needed:

   Table showing typical characteristics of DWPF HLW glass to be received at the repository.

7. What is the information needed for?

   Preparation of Waste Form Characteristics, Section 5.1.2.3. This will be Figure 5.1F.

8. What group is the probable information supplier?

   Systems Analysis Group.

9. When is the information needed?

   TBD.

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

    DWPF Project. ("Waste Forms Characteristics Report," for DWPF). LLNL has generated a report also ("Waste Forms Characteristics Report, " to be issued).

---

11. Response by (name):

12. Response date:

13. Response:

MGDS Annotated Outline Information Need Form
Form B: Information Response

Date: 4/17/92

1. Section No. & Title: **5.1 DESCRIPTION OF THE ENGINEERED BARRIER SYSTEMS**

2. Person Supplying Information: Hugh Benton (702) 794-1891

3. Phone No.:

4. Lead Author (Requester):

   Instructions: Information suppliers may use this form to communicate information which has been requested by lead authors via Information Request Forms. The Log Number on this form should be identical to the Log Number of the Information Request Form.

5. Response by Information Supplier:

Note: Attach additional sheets if necessary.

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

MGDS Annotated Outline Information Need Form
Form C: Information Request Tracking Log

Date: 4/17/92

Note: This is a recommended format for a manual tracking system. Other tracking methods such as a simple computer data base are also acceptable.

Date:

Lead Author:

Log No.	Section	Date Issued	Date Response Received

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

MGDS Annotated Outline

Section 5.2 Engineered Barrier System Compliance with 10 CFR 60

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5.2.2.2	Release Rate Performance Objective	5.2-4
5.2.3	Radiation Protection	5.2-5

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

LIST OF TABLES

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

LIST OF FIGURES

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

5.2 ENGINEERED BARRIER SYSTEM COMPLIANCE WITH 10 CFR 60

5.2.1 EBS Compliance with 10 CFR 60 Design Criteria

5.2.1.1 Waste Package Design Criteria

5.2.1.2 Waste Forms

5.2.1.3 Underground Facility Design Criteria

5.2.2 EBS Compliance with 10 CFR 60 Performance Objectives

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 up to 1000 years (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 (controlled release). By reference, the period of controlled release is extended to 10,000 years via 40 CFR Part 191. 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 has designed the waste packages to provide total containment during the containment period under the full range of anticipated repository conditions, recognizing

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

technological limitations and residual uncertainties. Use is made of a robust, multi-barrier package that will be tolerant to 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 were considered in the design and performance assessment (PA) activities.

[Compliance with the criteria for both the reference and alternative designs must be 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 compared 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 must be 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 would be assessed. This would include modifying performance allocations, as well as re-examining those barriers for which no allocation was taken previously. For example:

- Internal canisters

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

- Modifying the design
- Considering the interpretation of regulatory terms and the regulations themselves.

5.2.2.1 Containment Performance Objective

Performance assessments were 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 SCP were compared with those generated as a result of the test program. Depending on the material, these tests included 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 history of the prototype containers and the various barriers was reviewed to confirm that the specifications have been met. Particular attention was paid to the non-destructive examination of closures.

The assessments used individual mechanistic waste package degradation codes developed by the Waste Package Development staff that were incorporated into an overall waste package performance code. The assessments included a range of environmental scenarios. This permitted 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 were performed to show that compliance has been achieved with sufficient margin. The result was compared to the performance objective for SCC to determine whether it has been met with

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

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 were evaluated using source terms developed for each scenario by the waste form performance activities.

5.2.2.2 Release Rate Performance Objective

Performance assessments were performed by the PA staff to determine whether the reference and alternate designs met the requirements of controlled release as defined in 10 CFR 60.113 and 40 CFR 191.13. The assessments included a range of environmental scenarios. Release was calculated based on waste package and total system computational models. However, compliance focusses on the release from the EBS and not on the individual waste packages. The computational models include the diffusional releases from the packages and the EBS based on the most likely ground water migration processes. These were integrated over all of the likely processes as a function of time to determine the release to the accessible environment.

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 provided suggested changes to these values and therefore, interfaces with both the design and testing efforts. Both qualitative and quantitative sensitivity and uncertainty analyses were performed to show that compliance has been achieved with sufficient margin.

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

Analyses were also performed with the alternative design to determine whether it provided longer radionuclide isolation.

5.2.3 Radiation Protection

Skeleton text has not been developed for this subsection.

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

REFERENCES

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

MGDS Annotated Outline Planning Package
Form 1: Text

Date: 4/17/92

1. Section No. & Title: **5.2 ENGINEERED BARRIER SYSTEM COMPLIANCE WITH 10 CFR 60**

2. Lead Author & Phone No. Paul Childress (702) 794-18242.

3. First Phase Planning Package Due: 6/21/91

   Second Phase Planning Package Due: 10/18/91

   First Phase Skeleton Draft Due: 12/30/91

   Second Phase Skeleton Draft Due: 3/15/92

4. Plan Approved: W.R. Griffin 8/27/91
   (Licensing Mgr & Lead Author)

5. Section Summary (Approximately 100 Words):

   Section 5.2 provides a description of the EBS design criteria and industry codes and standards used in the EBS design process. Design parameters and goals are described in relation to the design criteria and how demonstration of satisfying these goals will show compliance with the applicable requirements of 10 CFR 60.

6. Opening Statement

   The EBS has been designed in accordance with specific criteria, the satisfaction of which will allow the demonstration of compliance with all applicable requirements of 10 CFR 60.

7. Main Body Outline: See attached.

8. Conclusion:

   The engineered barrier system (EBS) has been developed to satisfy the design criteria of 10 CFR 60. Testing, modeling, code development, and performance assessment activities have been used to understand, describe, simulate, and predict the integrated behavior of the EBS. These activities demonstrate that the radionuclide containment and release performance objectives are met with high reliability and confidence.

9. Support Authors & Their Assignments:

   5.2.1.3 Underground Facility - Paul McKie

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

7. Main Body Outline: (Continued)

5.2 ENGINEERED BARRIER SYSTEM COMPLIANCE WITH 10 CFR 60

5.2.1 EBS Compliance with 10 CFR 60 Design Criteria

An introductory description and discussion of the design criteria for waste package, waste forms, and the underground facility are provided in this section in response to 10 CFR 60.135 and 10 CFR 60.133(h), respectively.

5.2.1.1 Waste Package Design Criteria

The design criteria of 10 CFR 60.135 are discussed in terms of specific requirements imposed on the waste package relative to:

- Preventing compromise of waste package functions
- Preventing compromise of underground facility performance
- Preventing compromise of geologic setting performance
- Consideration of factors such as radionuclide solubility, corrosion, gas generation, thermal effect, radiolysis, and mechanical strength of containment barriers
- Consideration of explosive, pyrophoric, and chemically reactive materials, free liquids handling and package identification.

Applicable industry codes and standards and design parameters and goals used to meet the design criteria are discussed. A discussion of how these codes, standards, and parameter goals result in compliance with the criteria is provided. To the extent applicable, a description of the modeling and analyses used to demonstrate that the design parameter goals are met is provided along with a thorough discussion of the bases for the models. The variability and uncertainties associated with the databases, models, and analysis results is also described.

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

7. Main Body Outline: (Continued)

5.2.1.2 Waste Forms

The design criteria of 10 CFR 60.135 related to the waste forms are discussed in terms of the specific requirements imposed. These relate to:

- Assurance that the waste form is in the solid form
- Particulate waste form consolidation to limit availability and generation of particulates
- Assurance that the waste will be non-combustible.

Applicable design parameters and goals used to meet the design criteria are discussed. A discussion of how these parameter goals result in compliance with the criteria is provided. To the extent applicable, models and analyses used to demonstrate that parameter goals are met and the bases for the models and analysis are described. The associated variabilities and uncertainties will also be discussed.

5.2.1.3 Underground Facility Design Criteria

The design criterion for the underground facility that is considered part of the EBS as defined in 10 CFR 60.133(h) is discussed in terms of specific requirements imposed to satisfy this criterion. The criterion is interpreted to apply only to the overall system performance objective after permanent closure (i.e., that the engineered barriers shall be designed to **assist** the geologic setting in ensuring that releases of radionuclides to the accessible environment following permanent closure conform to the standards established by the Environmental Protection Agency with respect to both anticipated and unanticipated processes and events).

Applicable industry codes and standards and design parameters and goals used to meet this criterion are discussed. A discussion of how these codes, standards, and parameter goals result in compliance with the criterion is provided.

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

7. Main Body Outline: (Continued)

5.2.1.3 Underground Facility Design Criteria (Continued)

To the extent applicable, a description of the models and analyses used to demonstrate that the design parameter goals are met is provided along with a thorough discussion of the bases for the models. Variabilities and uncertainties associated with the data bases, models and analysis results are described.

5.2.2 EBS Compliance with 10 CFR 60 Performance Objectives

An introductory discussion of the meaning and the interpretation of the HLW containment and release rate performance objectives of 10 CFR .113(c) is provided.

The computer codes used to assess EBS performance in terms of the containment and release rate performance objectives is described. The testing and model development efforts used to support the codes are discussed, including techniques used to extrapolate the short term test behavior.

Uncertainties in the test data, models, codes, and code predictions are discussed.

The allocation of performance functions and performance parameter goals is described. Assumptions of anticipated processes and events are described.

5.2.2.1 Containment Performance Objective

A description of the analyses, prediction, and evaluation of radionuclide containment in terms of the interpreted containment performance objective is provided. The sources of uncertainty in the prediction that apply specifically to containment of radionuclides are addressed. Considerations of the favorable and potentially adverse conditions described in 10 CFR 60.122 are discussed.

5.2.2.2 Release Rate Performance Objective

A description of the analyses, prediction, and evaluation of radionuclide release from the EBS is provided in terms of the interpreted release rate performance objective. The sources of uncertainty in the prediction that apply specifically to radionuclide release after the containment period are addressed.

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

7. Main Body Outline: (Continued)

5.2.2.2 Release Rate Performance Objective (Continued)

Considerations of the favorable and potentially adverse conditions described in 10 CFR 60.122 are discussed.

5.2.3 Radiation Protection

Descriptions are provided for the measures to be taken to maintain radiological safety of the workers in the underground facility during handling, storage, emplacement, potential retrieval and isolation of the waste packages under normal operating conditions, anticipated operational occurrences, and accident conditions. The projected radiation exposures to workers and to members of the public are tabulated for each of the operations and conditions described above until permanent closure.

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

MGDS Annotated Outline Planning Package
Form 2: Figures & Tables

Date: 4/17/92

Section No. & Title: **5.2 EBS COMPLIANCE WITH 10 CFR 60**

Lead Author & Phone No. Paul Childress (702) 794-1824

A. Table No. **5.2A**

Title: **EBS Design Requirements, Parameters, and Goals**

Content: (Reference paragraph 5.2.1.1)

This table will correlate each of the design criteria from 10 CFR 60 with derived design requirements, design parameters, and parameter goals that, if satisfied, would ensure that the criteria are met.

B. Figure No. **5.2A**

Caption: **Evaluation of EBS to Contain Radionuclides**

Content: (Reference paragraph 5.2.2.1)

Plot of a measure of radionuclide containment (measure TBD) versus time.

C. Figure No. **5.2B**

Caption: **Evaluation of EBS to Limit Radionuclide Release**

Content: (Reference paragraph 5.2.2.2)

Plot of a measure of radionuclide release (measure TBD) versus time.

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

Section No. & Title: **5.2 EBS COMPLIANCE WITH 10 CFR 60**

Lead Author & Phone No. Paul Childress (702) 794-1824

A. Table No. **5.2B**

Title: **Projected Radiation Exposure to Workers and Public**

Content: (Reference paragraph 5.2.3.1)

This table will tabulate the projected radiation exposure to both repository underground facility workers and the general public based on handling, storage, emplacement, potential retrieval, and isolation of waste packages under normal operating conditions, anticipated operational occurrences, and accident conditions.

B. Figure/Table No.

Caption/Title:

Content:

C. Figure/Table No.

Caption/Title:

Content:

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

MGDS Annotated Outline Planning Package
Form 3: References

Date: 4/17/92

Section No. & Title:

Lead Author & Phone No.

Instructions: List all books, articles, or other references that are expected to be used for the section. Indicate whether references are draft or final, and whether they are publicly available (i.e., published). Refer to the Writer's Guide, Appendix D of the Annotated Outline Management Plan for guidance on formatting reference information.

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MGDS Annotated Outline Information Need Form
Form A: Information Request

Date: 4/17/92

1. Log number:

2. Section no. & title: **5.2 ENGINEERED BARRIER SYSTEM COMPLIANCE WITH 10 CFR 60**

3. Lead author & phone no: **Paul Childress (702) 794-1824**

4. Information request date:

5. Work location:

6. Type of information needed:

7. What is the information needed for?

8. What group is the probable information supplier?

9. When is the information needed?

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 B: Information Response

Date: 4/17/92

1. Section No. & Title:

2. Person Supplying Information:

3. Phone No.:

4. Lead Author (Requester): Marshall Weaver (702) 794-1871

   Instructions: Information suppliers may use this form to communicate information that has been requested by lead authors via Information Request Forms. The Log No. on this form should be identical to the Log No. of the Information Request Form.

5. Response by Information Supplier:

Note: Attach additional sheets if necessary.

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

MGDS Annotated Outline Information Need Form
Form C: Information Request Tracking Log

Date: 4/17/92

Note: This is a recommended format for a manual tracking system. Other tracking methods such as a simple computer data base are also acceptable.

Date:

Lead Author:

Log No.	Section	Date Issued	Date Response Received

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

Chapter 6.0 Overall System Performance Assessment

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6.0 OVERALL SYSTEM PERFORMANCE ASSESSMENT 6.0-1

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LIST OF FIGURES

Page

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6.0 OVERALL SYSTEM PERFORMANCE ASSESSMENT

This chapter describes quantitative analyses of the postclosure system performance carried out to demonstrate compliance with the requirements of 10 CFR 60.112. It also describes or refers to such additional information as is necessary to support those analyses.

The descriptions in this chapter indicate what conceptual models were incorporated into the computational models used in the Total System Performance Assessment (TSPA), the processes incorporated into those models, and the events and scenarios evaluated using those models. The results obtained are discussed in relation to the demonstration of compliance with requirements of 40 CFR 191 and 10 CFR 60.112. Justification for the exclusion of processes from the models, or of events and scenarios from the assessment is included either in the text or in references cited. Verification of codes and validation of models is incorporated primarily by reference.

The assessment of compliance with the pre-waste emplacement ground water travel time criterion of 10 CFR 60.113(b) is discussed in Section 3.3.5. Preclosure performance with respect to compliance with the criteria of 10 CFR 60.111 is discussed in Section 4.5. Compliance with the performance criteria of 10 CFR 60.113 for the engineered barrier system is discussed in Section 5.2.

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

REFERENCE

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

1. Section No. & Title: **6.0 OVERALL SYSTEM PERFORMANCE ASSESSMENT**

2. Lead Author & Phone No. Jim Duguid
703-204-8851

3. First Phase Planning Package Due: 6/21/91

   Second Phase Planning Package Due: 10/18/91

   First Phase Skeleton Draft Due: 12/30/91

   Second Phase Skeleton Draft Due: 3/15/92

4. Plan Approved: W.R. Griffin 8/27/91
(Licensing Mgr & Lead Author)

5. Section Summary (Approximately 100 Words):

   This chapter describes the quantitative analyses of overall system performance that demonstrate compliance with the regulatory requirements of 10 CFR 60.112 (post-closure performance). This description includes or refers to such additional non-quantitative information as may be necessary to support the quantitative analyses. Pre-closure performance is discussed in Section 4.5 in accordance with requirements of 10 CFR 60.111. Performance of the engineered barrier system is discussed in Section 5.2 per requirements of 10 CFR 60.113.

6. Opening Statement: None.

7. Main Body Outline: TBD.

8. Conclusion: TBD.

9. Support Authors & Their Assignments:

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

MGDS Annotated Outline Planning Package
Form 2: Figures & Tables

Date: 4/17/92

Section No. & Title: **6.0 OVERALL SYSTEM PERFORMANCE ASSESSMENT**

Lead Author & Phone No. Jim Duguid
703-204-8851

A. Table No.

Title:

Content:

B. Table No.

Title:

Content:

C. Table No.

Title:

Content:

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MGDS Annotated Outline Planning Package
Form 3: References

Date: 4/17/92

Section No. & Title: **6.0 OVERALL SYSTEM PERFORMANCE ASSESSMENT**

Lead Author & Phone No. Jim Duguid
703-204-8851

Instructions: List all books, articles, or other references that are expected to be used for the section. Indicate whether references are draft or final and whether they are publicly available (i.e., published). Refer to the Writer's Guide, Appendix D of the Annotated Outline Management Plan for guidance on formatting reference information.

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MGDS Annotated Outline Information Need Form
Form A: Information Request

Date: 4/17/92

1. Log number:

2. Section no. & title: **6.0 OVERALL SYSTEM PERFORMANCE ASSESSMENT**

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:

7. What is the information needed for?

8. What group is the probable information supplier?

9. When is the information needed?

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

---

11. Response by (name):

12. Response date:

13. Response:

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MGDS Annotated Outline Information Need Form
Form B: Information Response

Date: 4/17/92

1. Section No. & Title: **6.0 OVERALL SYSTEM PERFORMANCE ASSESSMENT**

2. Person Supplying Information:

3. Phone No.:

4. Lead Author (Requester): Marshall Weaver 702-794-1871

   Instructions: Information suppliers may use this form to communicate information that has been requested by lead authors via Information Request Forms. The Log Number on this form should be identical to the Log Number of the Information Request Form.

5. Response by Information Supplier:

Note: Attach additional sheets if necessary.

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

MGDS Annotated Outline Information Need Form
Form C: Information Request Tracking Log

Date: 4/17/92

Note: This is a recommended format for a manual tracking system. Other tracking methods such as a simple computer data base are also acceptable.

Date:

Lead Author:

Log. No.	Section	Date Issued	Date Response Received

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MGDS Annotated Outline

Section 6.1 Basic Approach

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

6.1 BASIC APPROACH

The Performance Assessments conducted for this License Application consisted of a sequence of assessments, each of which constitutes a nested collection of analyses integrated through a comprehensive top-level model. These assessments, each of which incorporates site characteristics, design data, and other relevant information available at the time of the analysis, demonstrate successive stages in the development of understanding of the system, in order to demonstrate reasonable assurance that the repository complies with the requirements of 10 CFR 60.112 and 40 CFR 191. The scope of each iteration of the Total System Performance Assessment is summarized and documented in Table 6.1A.

The results of each iteration in the sequence of assessments were presented to the NRC staff for comment. Comments from NRC and other concerned parties were considered in developing successive performance assessments. Each iteration focused on resolution of selected issues in regulatory compliance. Table 6.1B shows a complete list of issues, the status of their resolution, and cites topical reports addressing those issues. With respect to compliance, the most prominent features of each iteration of performance assessment are the products of computational models. However, reasonable assurance of compliance depends substantially upon information from evaluation of natural analogs and confirmatory tests. Underlying the selection of data, of alternate conceptual models, of processes and events, and of all supporting analyses and evaluations, lies the judgment of experts. To the extent possible, the elicitation of judgment is documented. The input data set for each assessment is cited in Table 6.1C. Iterative assessment

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and review enables resolution of issues at successive stages of development, and the status of resolution of issues tabulated in Table 6.1B indicates the extent to which issues have been resolved prior to submission of this Safety Analysis Report (SAR).

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Table 6.1A. Summary and Documentation of Each Iteration of Performance Assessment

Iteration	Models Used	Scenarios	Documentation
1	Primarily based on systems models with input from subsystem models and a limited input from process models.	Human Intrusion Seismicity Volcanism	SAND_____, 1992.
2			
3			
. . . .			

Note: This table will be completed using Information Need Log No. JOD-1.

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Table 6.1B. Status of Issue Resolution Using Performance Assessment

Issue	Status		Topical Report (Reference)
	Resolved	Open	
1. Erosion		x	
2. Volcanism		x	
.			
.			
.			

Note: This table will be completed using Information Need Log No. JOD-2.

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Table 6.1C Performance Assessment Input Data for Each Iteration

Iteration	Data Documentation
1	(References(s))
2	
3	
.	
.	
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Note: This table will be completed using Information Need Log No. JOD-1.

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6.1.1 Conceptual Background for the Assessment of Overall System Performance

The overall system performance was evaluated through modeling of the following components:

- Radionuclide release from the engineered barrier system
- Fluid flow in the geologic units
- Radionuclide transport to the accessible environment
- Dose to man and radionuclide release to the accessible environment.

The relationship among these components is shown in Figure 6.1.1A. Each of these components was modeled at more than one level of detail. The levels of detail of PA models form a model hierarchy which can be envisioned as a triangle with the most complex models forming the base and the least complex models near the apex (Figure 6.1.1B). The most complex models are process models; the least complex are systems models, and the intermediate are subsystem models, sometimes called domain models. For visualization purposes the hierarchy of models is thought of as being composed of three levels. However, the division between process and subsystem models is not always distinct (e.g., some process models grade uniformly into subsystem models and vice versa). For this reason the boundary between process and subsystem models has been shown as a dashed line on Figure 6.1.1B.

Process models are usually deterministic numerical codes that incorporate coupled interactions such as water, water vapor, gas, and heat flow. These models closely represent the physical

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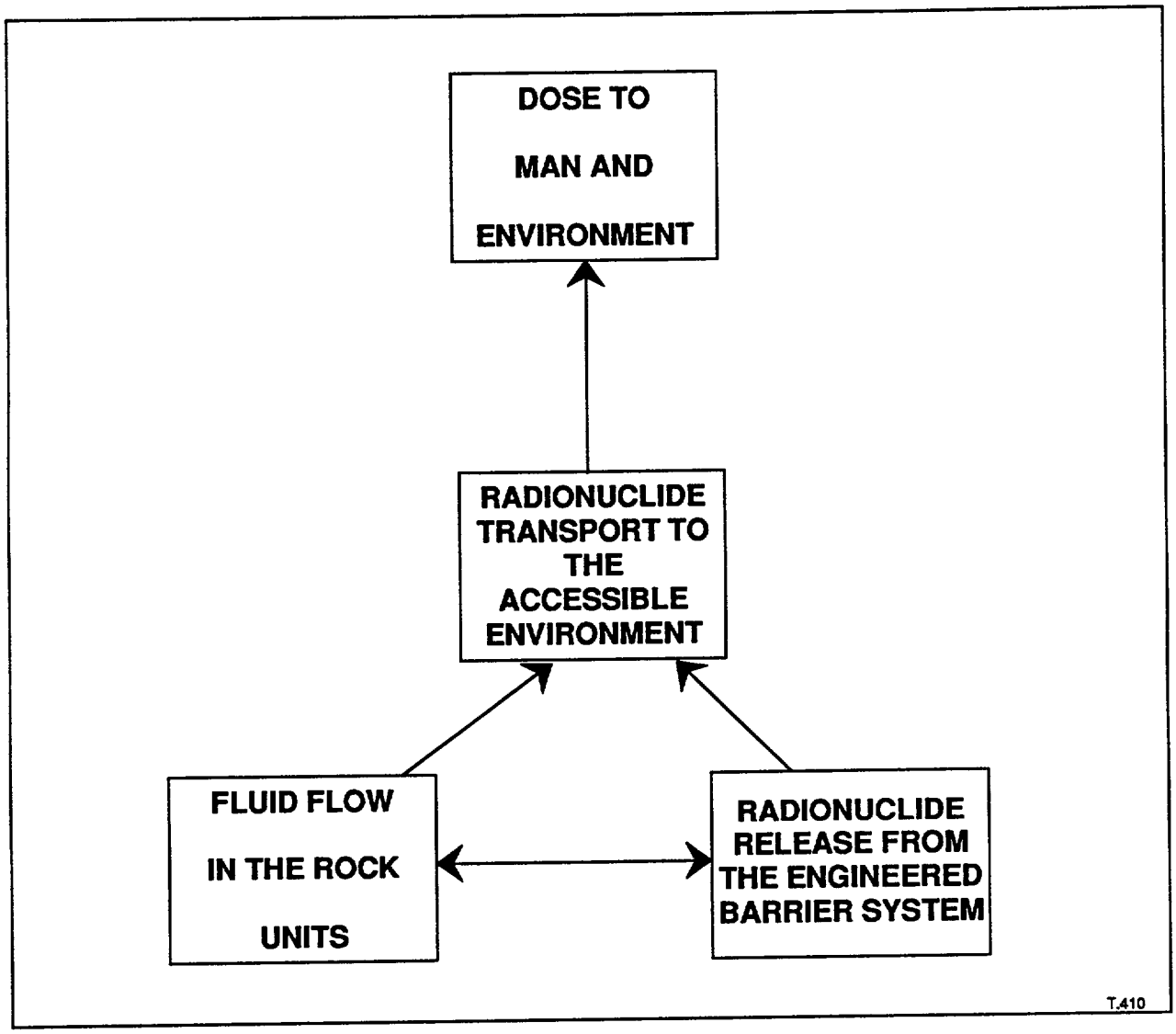

Figure 6.1.1A. Components of Overall System Performance Assessment

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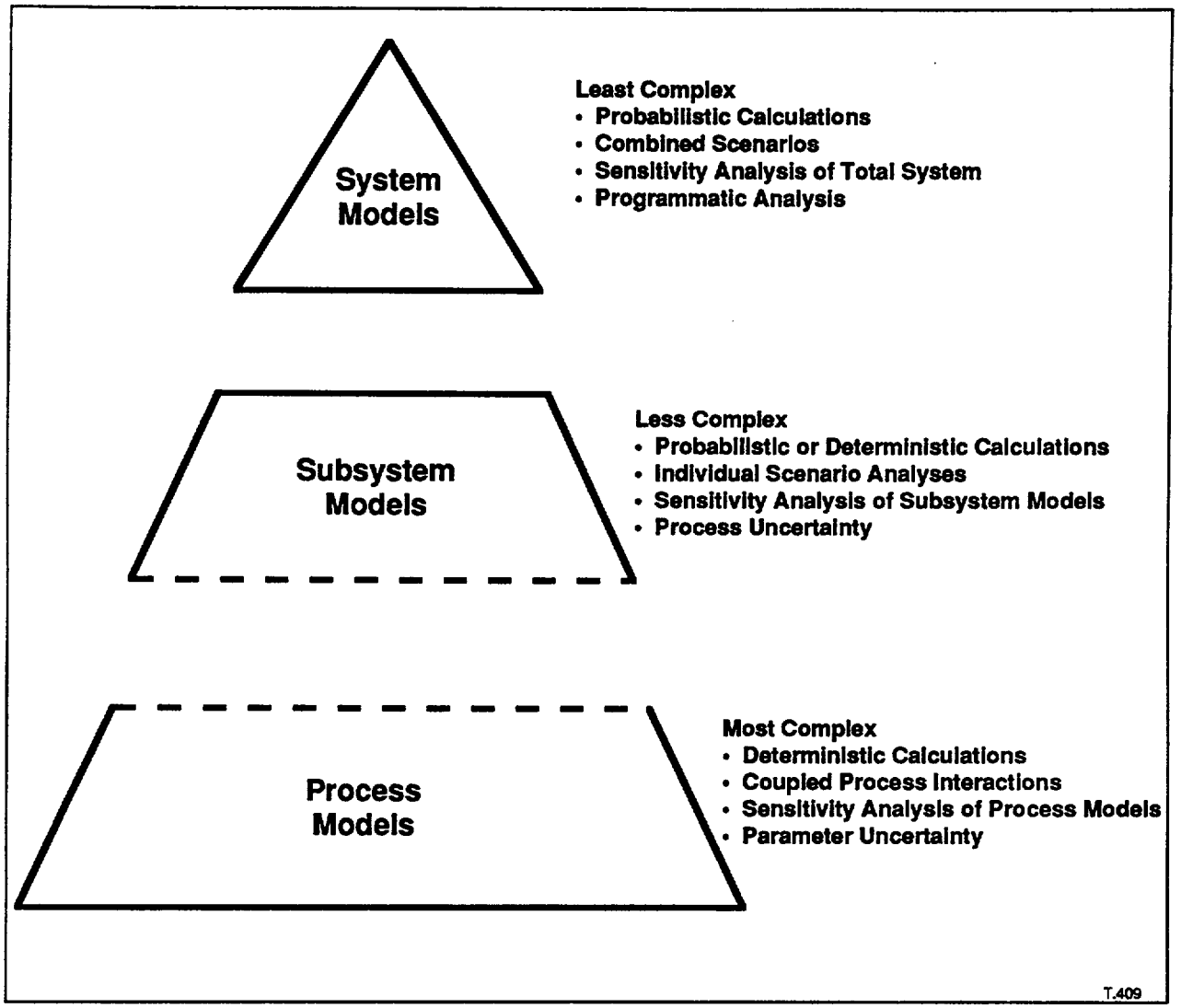

Figure 6.1.1B Hierarchy of Models Used in Performance Assessment

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(chemical) processes that occur and are used to evaluate the effects of parameter uncertainty by conducting parameter sensitivity analyses over the ranges of model input parameters that exist at the site.

Subsystem models are either deterministic or probabilistic models which are used in analysis of individual scenarios, bounding analyses, or determinations of process uncertainty. An example of a subsystem model is the waste package model which incorporates chemical/geochemical, flow, stress, and thermal processes in an abstracted (simplified) form. Subsystem models are used to investigate process uncertainty through incorporation of the range of expected processes which could occur at the site.

System models are probabilistic codes which combine potential site scenarios. They are the least complex models which are used to demonstrate compliance with regulations (i.e., calculation of the complementary cumulative distribution function to meet 40 CFR 191). They represent the most abstracted models and are used primarily for bounding analyses of scenarios and combinations of scenarios.

The hierarchy of models used in PA (Figure 6.1.1B) is thought of as containing models which are more complete and more sensitive at the base. Toward the apex, models contain all of the major components of models at the base, but process description are in an abstracted (less detailed) form. For this reason, model uncertainty and conservatism increases toward the apex of the hierarchy triangle, and parameter sensitivity increases toward the base.

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Iterative PA can be envisioned as beginning at the base of the triangle and conducting sensitivity analyses over the existing range of parameters and scenarios required to comply with regulations. Transfer between hierarchy levels is accomplished by using these results of process models to formulate input for subsystem models, and using subsystem results as a basis for input for system models. The results of the system models are then compared with those of the subsystem and process models to ensure that the total system of results are consistent. In other words, one iteration would include beginning at the base of the triangle and working upwards toward the apex (e.g., generating the transfer functions between process and subsystem and between subsystem and system models); then looking back down the levels of detail in the triangle to ensure that the results of the system models are consistent with the less abstracted models toward the triangle base. For the second iteration, the process model results would only need to be recalculated if new site data or a change in a scenario extended a parameter range beyond that of the sensitivity analyses conducted for the first iteration. This vision of exercising the hierarchy of models to yield reasonable assurance in the results of the overall system performance is a tool to aid in understanding the interrelationships among the levels of model complexity.

The iterative performance assessment at the Yucca Mountain site began in 1991 with a total system PA in which largely system and subsystem models were exercised (SAND_____, 1992) (Information Need Log No. JOD-3). The complexity of the modeling approach increased with each iteration and results were used to guide site characterization and design, to guide model development, and to provide a basis for interactions with the NRC and the public.

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For each iteration, PA information from other components of the MGDS programs were used; the PA was conducted, and the results were disseminated among the components of the program. Figure 6.1.1C shows the interactions between PA and the other components of the MGDS program (e.g., regulation, design, site characterization, model development, and the public). This process can be thought of as information being fed into PA, analyses being conducted, and information being fed out of PA to MGDS components with each iteration (Figure 6.1.1C). In this way, the results of PA were used to influence design and site characterization and to present results to the NRC and the public with each iteration. NRC and public comments were considered in developing the scope of the next iteration. As shown in Figure 6.1.1B, results at each level were calculated with each iteration, where necessary, as new data, scenarios, and models became available during the iterative process.

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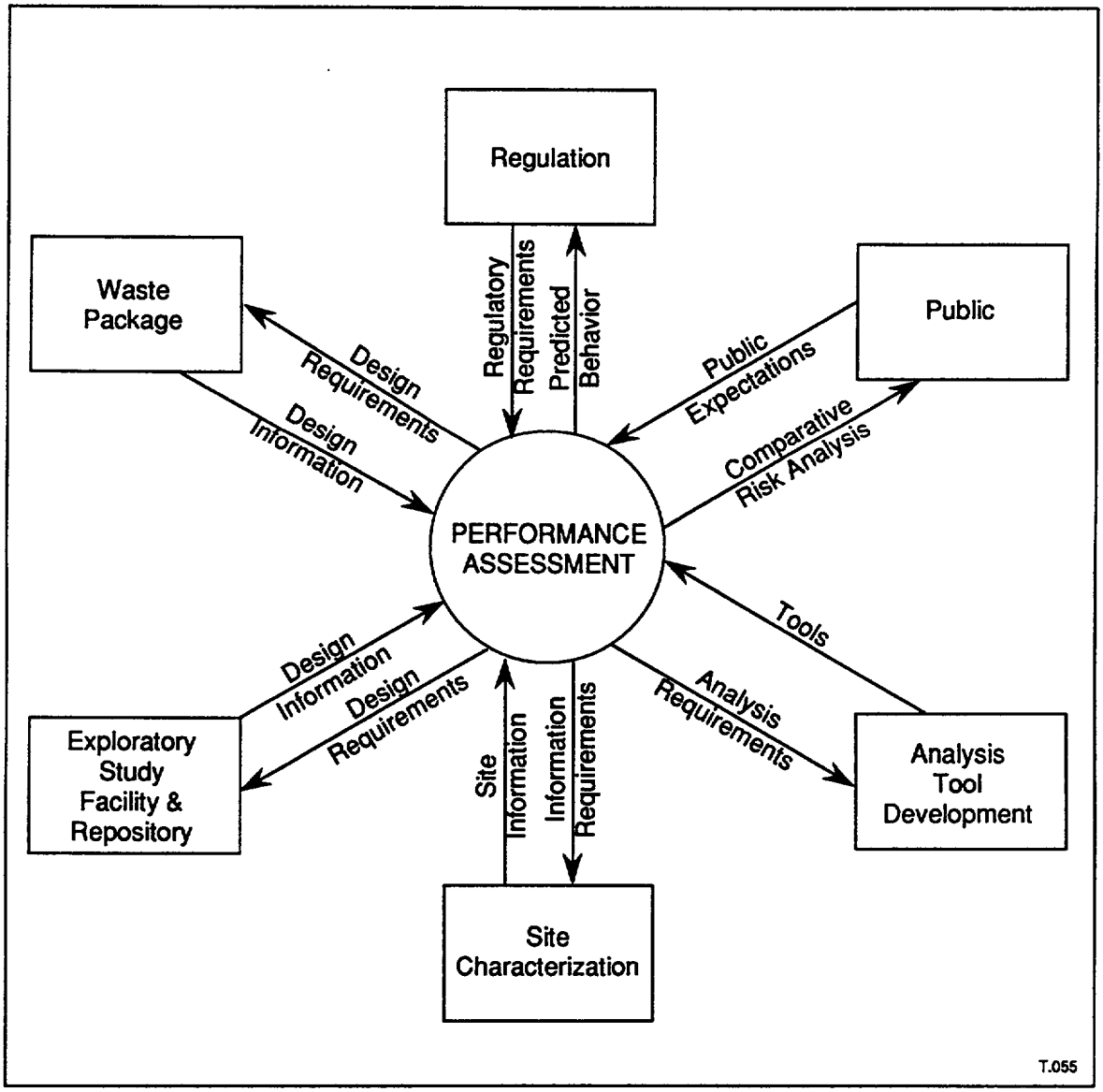

Figure 6.1.1C. Interactions Between PA and Other Components of the MGDS Program for Each Iteration

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6.1.2 Mathematical Background for the Assessment of Overall System Performance

Note: This section will be completed using Information Need Log No. JOD-4.

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REFERENCE

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

MGDS Annotated Outline Planning Package
Form 1: Text

Date: 4/17/92

1. Section No. & Title: **6.1 BASIC APPROACH (OVERALL SYSTEM PERFORMANCE ASSESSMENT)**

2. Lead Author & Phone No. Jim Duguid
703-204-8851

3. First Phase Planning Package Due: 6/21/91

   Second Phase Planning Package Due: 10/18/91

   First Phase Skeleton Draft Due: 12/30/91

   Second Phase Skeleton Draft Due: 3/15/92

4. Plan Approved: W.R. Griffin 8/27/91
   (Licensing Mgr & Lead Author)

5. Section Summary (Approximately 100 Words):

   This section describes the conceptual and mathematical background for the assessments of overall system performance.

6. Opening Statement:

7. Main Body Outline:

   6.1.1 Conceptual background for the assessment of Overall System Performance

   6.1.2 Mathematical background for the assessment of Overall System Performance

   This section should contain a brief discussion of the types of mathematical models used in performance assessment with examples of models which use each type (e.g., Integrated Finite Difference; TRACR3D). Types of probabilistic methods used in the analyses should be described. Also included should be a discussion of how the CCDF was formed and how uncertainties are incorporated (e.g., mean CCDF or uncertainty of the uncertainty).

8. Conclusion:

9. Support Authors & Their Assignments:

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

Section No. & Title: **6.1 BASIC APPROACH (OVERALL SYSTEM PERFORMANCE ASSESSMENT)**

Lead Author & Phone No. Jim Duguid
703-204-8851

A. Table No. **6.1A**

Title: **Summary of Performance Assessment Iterations Completed**

Content:

Iteration	Models Used	Scenarios	Documentation
0	Primarily Systems Models	Human intrusion, seismicity, volcanism	SAND _____, 1992
2	-	-	-

[Will be completed as per information need Log no. JOD-1]

B. Table No. **6.1B**

Title: Status of Issue Resolution using Performance Assessment

Content:

Issue	Status		Topical Report Reference
	Resolved	Open	
1. Erosion		x	(none)
2. Volcanism		x	
3.			

[Will be completed as per information need Log no. JOD-2]

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

Section No. & Title: **6.1 BASIC APPROACH (OVERALL SYSTEM PERFORMANCE ASSESSMENT)**

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

C. Table No. **6.1C**

Title: Performance Assessment Data Input for each Iteration

Content:

Iteration	Data Documentation
1	SAND ____, 1992
2	
3	

[Will be completed as per information need Log no. JOD-1]

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

MGDS Annotated Outline Planning Package
Form 3: References

Date 4/17/92

Section No. & Title: **6.1 BASIC APPROACH (OVERALL SYSTEM PERFORMANCE ASSESSMENT)**

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

Instructions: List all books, articles, or other references that are expected to be used for the section. Indicate whether references are draft or final and whether they are publicly available (i.e., published). Refer to the Writer's Guide, Appendix D of the Annotated Outline Management Plan for guidance on formatting reference information.

1. U.S. Department of Energy, 1988, Site Characterization Plan, Yucca Mountain Site, Nevada Research and Development Area, Nevada. DOE/RN-0199, Office of Civilian Radioactive Waste Management, December 1988.

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

MGDS Annotated Outline Information Need Form
Form A: Information Request

Date: 4/17/92

1. Log number: **JOD-1**

2. Section no. & title: **6.1 BASIC APPROACH (OVERALL SYSTEM PERFORMANCE ASSESSMENT)**

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:

   Data input documentation and results (documentation) for each iteration of PA.

7. What is the information needed for?

   Input to Chapter 6 of SAR, and input to Table 6.1A and 6.1C.

8. What group is the probable information supplier?

   Performance Assessment, Bob Andrews, M&O.

9. When is the information needed?

   At the end of each PA iteration, Iteration 2, Sept. 1993, and annually thereafter.

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

    Iteration 0, Total System Performance, Assessment SAND _____, 1992.
    Holly Dockery SNL. YMP SCP.

---

11. Response by (name):

12. Response date:

13. Response:

MGDS Annotated Outline Information Need Form
Form A: Information Request

Date: 4/17/92

1. Log number: **JOD-2**

2. Section no. & title: **6.1 BASIC APPROACH (OVERALL SYSTEM PERFORMANCE ASSESSMENT)**

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 current issues where PA will be used in their resolution, listing of issues resolved, and topical report references for resolved issues.

7. What is the information needed for?

   Completion of Table 6.1B.

8. What group is the probable information supplier?

   Licensing, Bill Griffin, M&O.

9. When is the information needed?

   Annually at the end of each fiscal year (September 30) until SAR is complete.

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

    Currently DOE has a preliminary issue list. YMP SCP.

---

11. Response by (name):

12. Response date:

13. Response:

MGDS Annotated Outline Information Need Form
Form A: Information Request

Date: 4/17/92

1. Log number: **JOD-3**

2. Section no. & title: **6.1.1 CONCEPTUAL BACKGROUND FOR THE ASSESSMENT OF OVERALL SYSTEM PERFORMANCE**

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:

   Reference.

7. What is the information needed for?

   Final documentation of Iteration 1 of Total System PA.

8. What group is the probable information supplier?

   SNL, Holly Dockery.

9. When is the information needed?

   September 30, 1992.

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

---

11. Response by (name):

12. Response date:

13. Response:

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MGDS Annotated Outline Information Need Form
Form A: Information Request

Date: 4/17/92

1. Log number: **JOD-4**

2. Section no. & title: **6.1.2 MATHEMATICAL BACKGROUND FOR THE ASSESSMENT OF OVERALL SYSTEM PERFORMANCE**

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:

   Description of types of models used in Iteration 1 of PA, and description of how the CCDF was formed and an interpretation of the uncertainty incorporated in the CCDF.

7. What is the information needed for?

   Completing a first draft of Section 6.1.2.

8. What group is the probable information supplier?

   Jim Duguid, Scientific Models, and Bob Andrews, PA.

9. When is the information needed?

   September 30, 1993.

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 B: Information Response

Date 4/17/92

1. Section No. & Title: **6.1 BASIC APPROACH (OVERALL SYSTEM PERFORMANCE ASSESSMENT)**

2. Person Supplying Information:

3. Phone No.:

4. Lead Author (Requester): Jim Duguid 703-204-8851

   Instructions: Information suppliers may use this form to communicate information that has been requested by lead authors via Information Request Forms. The Log Number on this form should be identical to the Log Number of the Information Request Form.

5. Response by Information Supplier:

Note: Attach additional sheets if necessary.

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

MGDS Annotated Outline Information Need Form
Form C: Information Request Tracking Log

Date: 4/17/92

Note: This is a recommended format for a manual tracking system. Other tracking methods such as a simple computer data base are also acceptable.

Date:

Lead Author:

Log. No.	Section	Date Issued	Date Response Received

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

Section 6.2 System Description

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6.2.2	Potentially Disruptive Processes and Events	6.2-5

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6.2.1G Justification of Conceptual Models Not Included in the Performance Assessement 6.2-4

6.2.2A Location and General Effects of Potential Disruptive Processes and Event 6.2-6

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

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

6.2 SYSTEM DESCRIPTION

This section describes the conceptual models, and processes and events that were analyzed to assess the overall repository system performance. The system consists of the geologic and hydrogeologic systems within the controlled zone as they are influenced by natural processes and events, thermal loading, and human factors over the next 10,000 years and beyond. The local hydrogeologic system within the controlled zone is related to the regional 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 zone and the region.

6.2.1 Conceptual Models

The potential conceptual model alternatives that could be used for evaluation of system performance were developed and documented (M&O Information Need Log No. JOD-5, 1992). The categories in which conceptual models were considered are related directly to the engineered barrier system (waste package), the repository as influenced by thermal loading (rock mechanics), water and gas flow in the unsaturated zone, water flow in the saturated zone, radionuclide transport in both the unsaturated and saturated zones, and the natural barrier system (biosphere). The potential conceptual models that were considered were screened and either rejected or incorporated into the calculational models that were used in the overall system performance assessment that is presented in this SAR.

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

Tables 6.2.1A through 6.2.1F provide a summary of the remaining conceptual models in the categories of waste package, rock mechanics, unsaturated flow, saturated flow, radionuclide transport and biosphere, respectively. Table 6.2.1G provides the references for each category that justify elimination of the potential conceptual models that were not considered in this SAR. [Discussion to be completed per information, need Log Nos. JOD-6 and JOD-7].

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

Table 6.2.1C. Conceptual Models Used for Analysis of Unsaturated Flow

Calculational Model	Conceptual Models
TOUGH2 . . .	Porous Media Double Porosity Dual Continuum

Note: Tables 6.2.1A through 6.2.1F are similar in design and only 6.2.1C is shown here. These tables will be completed using Information Need Log No. JOD-6.

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

Table 6.2.1G. 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 Information Need Log No. JOD-7.

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

6.2.2 Potentially Disruptive Processes and Events

The potentially disruptive processes and events that could reasonably affect the geologic repository over the next 10,000 years are presented in Table 6.2.2A. These processes and events are categorized by their causes which are tectonic, geomorphic, climatic, and anthropogenic. Anthropogenic effects are either intentional (repository related) or inadvertent (due to human intrusion). Table 6.2.2A also indicates the location in which each of the processes and events are a consideration (e.g., 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.

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 effect 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 zone

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Table 6.2.2A. 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 zone and region	Alteration of flow paths
	• Seismicity	Region	Alternation of flow paths
	• Volcanism		
	- magmatic intrusion	Emplacement Area	Waste entrainment
	- hydrothermal intrusion	Controlled zone	Corrosional/leaching/migration
Geomorphic	• Erosion	Controlled zone	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 zone	Alteration of flow path and alteration of sorption
Climatic	• Infiltration	Controlled zone and region	Decreased travel time, increased leaching, and water table raise
	• Erosion/Mass Gravity		
	- Dams & Ponds	Controlled zone	Increased infiltration
Human	• Intrusion		
	- Drilling	Controlled zone	Waste exhumation, alteration of flow paths, and drinking water wells
	- Mining	Controlled zone	Exhumation of contaminated rock
	• Infiltration		
	- Ground-water injection/water spreading	Controlled zone	Increased infiltration, alteration of flow paths
	- Dams & Ponds	Controlled zone	Increased infiltration
	• Weapons Testing	Controlled zone	Alteration of flow paths

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could increase hydraulic conductivities and release perched ground water or decrease travel time from the repository to the accessible environment.

Geomorphic processes and events which were 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 which would make them more succeptable to mass gravity movements. 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 have been considered.

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 zone. For this reason, geochemical changes have been considered within the controlled zone in order to examine the potential

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

significance of these smaller effects beyond the emplacement area.

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 raise; all of which are important within the controlled zone. Increased infiltration in the region could alter regional ground water flow patterns which could affect flow paths.

The undisturbed repository behavior could be changed through future human actions. Human activties 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. In order to meet the requirements of 40 CFR 191, and because drilling and mining in search of natural resources could alter flow paths, intrusion has been considered within the controlled zone. Human activities could increase infiltration from water spreading, underground injection of water, or construction of dams and ponds within the controlled zone. Ground water withdrawal could alter the direction of flow and/or the rate of flow along flow paths. Weapons testing within the controlled zone could also alter water and gas flow paths.

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

REFERENCE

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

MGDS Annotated Outline Planning Package
Form 1: Text

Date 4/17/92

1. Section No. & Title: **6.2 SYSTEM DESCRIPTION (OVERALL SYSTEM PERFORMANCE ASSESSMENT)**

2. Lead Author & Phone No. Jim Duguid
703-204-8851

3. First Phase Planning Package Due: 6/21/91

   Second Phase Planning Package Due: 10/18/91

   First Phase Skeleton Draft Due: 12/30/91

   Second Phase Skeleton Draft Due: 3/15/92

4. Plan Approved: W.R. Griffin 8/27/91
(Licensing Mgr & Lead Author)

5. Section Summary (Approximately 100 Words):

   This section describes the conceptual models, processes, and events used to assess overall repository system performance. Because the supporting bases for the conceptual models, processes, and events are presented in other chapters, cross-references will be indicated where appropriate.

6. Opening Statement:

7. Main Body Outline: See attached.

8. Conclusion:

9. Support Authors & Their Assignments:

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

7. Main Body Outline (Continued)

6.2. SYSTEM DESCRIPTION

This section describes the conceptual models, processes, and events that were used to assess overall repository system performance. In general, the supporting bases for the conceptual models, processes, and events are presented in other chapters. In this section, they should be summarized in sufficient detail to provide a basis for the PAs of this chapter. To the extent that processes and events have previously been identified and described in Sections 3.2.1 and 3.2.2, only a listing of these processes and events need be presented in this section. If the identification of processes and events presented here is more (or less) extensive than that of Sections 3.2.1 and 3.2.2, the reasons for the differences should be presented.

6.2.1 Conceptual Models

Describe the conceptual models (and reasonable alternatives) applicable to the assessment of overall system performance. Provide the basis for excluding an alternative concept from the PA.

6.2.2 Potentially Disruptive Processes and Events

This section identifies all credible potentially disruptive processes and events that could significantly and adversely affect the post-closure performance of the overall repository system. Each process or event is described in terms of its cause (if known), its expected location or locations of occurrence, and, in general terms, its effects on the post-closure performance of the overall repository system (see Table 6.2A).

6.2.3 Undisturbed Performance Processes and Events

This section identifies all processes and events expected to affect the predicted post-closure behavior of the overall repository system in its undisturbed state. Each process or event is described in terms of its cause (if known), its expected location or locations of occurrence, and in general terms, its effects on the post-closure performance of the overall repository systems (see Table 6.2B).

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

Section No. & Title: **6.2 SYSTEM DESCRIPTION (OVERALL SYSTEM PERFORMANCE ASSESSMENT)**

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

A. Table No. **6.2A**

Title: **Potentially Disruptive Processes and Events**

Content:

Cause	Credible Potentially Disruptive Processes & Events that Could Significantly and Adversely Affect of the Post-Closure Performance of the Overall Repository System	Expected Location or Location Occurrence	Effects on the Post-Closure Performance (In general terms)
Cause Statement	Process	Here	Schedule Delay
Cause Statement	Process	There	Contamination
Unknown Cause	Process	Everywhere	Potential Worker Safety

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

Section No. & Title: **6.2 SYSTEM DESCRIPTION (OVERALL SYSTEM PERFORMANCE ASSESSMENT)**

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

B. Table No. **6.2B**

Title: **Undisturbed Performance Processes and Events**

Content:

Cause	Process and Events Expected to Affect the Predicted Post-Closure Behavior of the Overall Repository System in its Undisturbed State	Expected Location or Locations of Occurrence	Effects on the Post-Closure Performance (In general terms)
Cause Statement	Process	Here	Potential Collapse
Cause Statement	Process	There	Contamination
Cause Statement	Process	Everywhere	Excessive Heat

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

Section No. & Title: **6.2.1 CONCEPTUAL MODEL**

Lead Author & Phone No. Jim Duguid
703-204-8851

A. Table No. **6.2A**

Title: **Conceptual Models Used for Analysis of Waste Package Water Flow**

Content:

Calculation/Model	Conceptual Models
"AREST"	Uniform corrosion, etc.

B. Table No. **6.2B**

Title: **Conceptual Models Used for Analysis of Repository Thermomechnanical Effects**

Content:

Calculation/Model	Conceptual Models

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

Section No. & Title: **6.2.1 CONCEPTUAL MODEL**

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

C. Table No. **6.2C**

Title: **Conceptual Flow Models Used for Analysis of the Unsaturated Zone**

Content:

Calculation/Model	Conceptual Models
TOUGH2	Porous Media
	Double Porosity
	Dual Continuum

D. Table No. **6.2D**

Title: **Conceptual Models Used for Analysis of Saturated Ground Water Flow**

Content:

Calculation/Model	Conceptual Models

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

Section No. & Title: **6.2.1 CONCEPTUAL MODEL**

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

E. Table No. **6.2E**

Title: **Conceptual Models Used for Analysis of Radionuclides Transport**

Content:

Calculation/Model	Conceptual Models

F. Table No. **6.2F**

Title: **Conceptual Models Used for Analysis of the Biosphere**

Content:

Calculation/Model	Conceptual Models
GENII	Standard Man, etc.

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Section No. & Title: **6.2.1 CONCEPTUAL MODEL**

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

G. Table No. **6.2G**

Title: **Justification of Conceptual Models Not Included in the Overall Performance Assessment**

Content:

Area	Conceptual Models Eliminated	Documentation
Waste Package		Reference

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

Section No. & Title: **6.2 SYSTEM DESCRIPTION (OVERALL SYSTEM PERFORMANCE ASSESSMENT)**

Lead Author & Phone No. Jim Duguid 703-204-8851

Instructions: List all books, articles, or other references that are expected to be used for the section. Indicate whether references are draft or final and whether they are publicly available (i.e., published). Refer to the Writer's Guide, Appendix D of the Annotated Outline Management Plan for guidance on formatting reference information.

1.

2.

3.

4.

5.

6.

7.

8.

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MGDS Annotated Outline Information Need Form
Form A: Information Request

Date: 4/17/92

1. Log number: **JOD-5**

2. Section no. & title: **6.2.1 CONCEPTUAL MODEL**

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, M&O _____, 1992.

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, Bob Andrews, M&O.

9. When is the information needed?

   September 30, 1992.

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: 4/17/92

1. Log number: **JOD-6**

2. Section no. & title: **6.2.1 CONCEPTUAL MODEL**

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?

   September 30, 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: 4/17/92

1. Log number: **JOD-7**

2. Section no. & title: **6.2.1 CONCEPTUAL MODEL**

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?

   September 30, 1994.

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 License Application.

MGDS Annotated Outline Information Need Form
Form B: Information Response

Date: 4/17/92

1. Section No. & Title: **6.2 SYSTEM DESCRIPTION (OVERALL SYSTEM PERFORMANCE ASSESSMENT)**

2. Person Supplying Information:

3. Phone No.:

4. Lead Author (Requester): Jim Duguid 703-204-8851

   Instructions: Information suppliers may use this form to communicate information that has been requested by lead authors via Information Request Forms. The Log Number on this form should be identical to the Log Number of the Information Request Form.

5. Response by Information Supplier:

Note: Attach additional sheets if necessary.

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

MGDS Annotated Outline Information Need Form
Form C: Information Request Tracking Log

Date: 4/17/92

Note: This is a recommended format for a manual tracking system. Other tracking methods such as a simple computer data base are also acceptable.

Date:

Lead Author:

Log. No.	Section	Date Issued	Date Response Received

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

Section 6.3 Assessment of Compliance: Cumulative Release of Radioactive Materials

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6.3 ASSESSMENT OF COMPLIANCE: CUMULATIVE RELEASE OF RADIOACTIVE MATERIALS 6.3-1

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

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

LIST OF FIGURES

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

6.3 ASSESSMENT OF COMPLIANCE: CUMULATIVE RELEASE OF RADIOACTIVE MATERIALS

Skeleton Text Has Not Been Developed For This Section

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

REFERENCE

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

MGDS Annotated Outline Planning Package
Form 1: Text

Date 4/17/92

1. Section No. & Title: **6.3 ASSESSMENT OF COMPLIANCE: CUMULATIVE RELEASE OF RADIOACTIVE MATERIALS**

2. Lead Author & Phone No. Scott Sinnock (Sandia)
W. J. Leonard (Placeholder)
(702) 794-1821

3. First Phase Planning Package Due: 6/21/91

   Second Phase Planning Package Due: 10/18/91

   First Phase Skeleton Draft Due: 12/30/91

   Second Phase Skeleton Draft Due: 3/15/92

4. Plan Approved: W.R. Griffin 8/27/91
(Licensing Mgr & Lead Author)

5. Section Summary (Approximately 100 Words):

   This section provides an evaluation of the performance of the overall repository system in terms of cumulative releases of radioactive materials to the accessible environment for 10,000 years after repository closure.

6. Opening Statement:

   Same as item 5 above.

7. Main Body Outline: See attached.

8. Conclusion:

   The cumulative release of radioactive materials following permanent closure is in compliance with requirements 10 CFR 60.112 and the environmental protection standards issued by the EPA for both anticipated and unanticipated processes and events.

9. Support Authors & Their Assignments:

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

7. Main Body Outline (Continued)

6.3.0 Introduction

This section provides an evaluation of overall repository system performance in terms of cumulative releases of radioactive materials to the accessible environment for 10,000 years after repository closure. The description characterizes the predicted release resulting from each scenario that can materially affect repository performance and the combined release caused by all scenarios. This section also includes the results of sensitivity analyses identifying the features of the overall system that most significantly affect performance for each of the most significant scenarios.

6.3.1 Screening of Processes and Events

6.3.1.1 Screening of processes and events identified in Sections 6.2.2 and 6.2.3, above, using screening criteria specified in Table 6.3A, to eliminate those that are physically or logically unrealistic or are expected to have trivial consequences.

6.3.1.2 Listing of processes and events that are retained after completion of screening (see Table 6.3B). The listing includes all processes and events that may materially affect the PA.

6.3.1.3 Reasoned explanation, justified by data, demonstrating the absence of material affect on PA, for processes and events that have been eliminated from the postscreening listing (see Table 6.3C).

6.3.2 Scenario Development and Screening

6.3.2.1 The processes and events retained after the screening activity of section 6.3.1, above, have been used to formulate scenarios consisting of credible combinations and sequence of processes and events. One or more scenarios consist of the behavior of the overall system not disrupted by human intrusion or by the occurrence of unlikely natural events ("undisturbed performance").

6.3.2.2 The full set of scenarios were then screened to eliminate those physically or logically unrealistic, or did not pass the probability or consequence screens, not sufficiently credible to warrant further consideration or expected to have trivial consequences.

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

7. Main Body Outline (Continued)

6.3.2.2.1 The method used for forming scenarios (see Figure 6.3A).

6.3.2.2.2 The criteria used for scenario screening (see Table 6.3D).

6.3.2.2.3 The scenarios retained in the analysis after completion of screening (see Table 6.3E).

6.3.3 Consequence Analysis: Estimates of Cumulative Releases

6.3.3.1 This section describes the results of analyses projecting the performance of the overall repository system as influenced by the scenarios described (see Section 6.3.2, above, and Table 6.3E).

6.3.3.2 The results of the analyses are expressed in terms of the cumulative releases of radioactive materials to the accessible environment. (see Figures 6.3F through 6.3Gn.)

6.3.3.3 Description of the analytical methods (e.g., computer codes) used for these analyses. (see Table 6.3H.)

6.3.4 Probability Estimates

6.3.4.1 The probability of occurrence of each individual process and event identified in Section 6.3.1 that might lead to a significant release of radionuclides from the overall system (see Table 6.3-I).

6.3.4.2 Estimated probabilities or frequencies of occurrence for each of the scenarios described in Section 6.3.2 (see Table 6.3I).

6.3.4.3 Description of techniques used to estimate probabilities (e.g., predictive modeling or estimates from site characterization activities) and the criteria used for each technique (see Table 6.3K).

6.3.4.4 Explanation of how time-dependent probabilities have been assessed for scenarios that involve transient phenomena (see Table 6.3L).

6.3.4.5 Identification and discussion of uncertainties in the probabilities and the sources of uncertainty (see Tables 6.3I through 6.3L).

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

7. Main Body Outline (Continued)

6.3.4.6 Discussion of alternate approaches used for estimating probabilities when little or no theoretical, experimental, or historical data are available. The factual bases and rationale for the values adopted are discussed.

6.3.5 Compliance Assessment for Cumulative Releases

6.3.5.1 This section demonstrates that the overall system performance objective for cumulative releases in 10 CFR 60.112 is met. The scenario probabilities described in Section 6.3.4 and the estimates of overall repository system performance described in Section 6.3.3 are combined into a single "complementary cumulative distribution function" (CCDF) displaying the likelihood that cumulative releases of radioactive material to the accessible environment over 10,000 years will not exceed the release limits of the EPA standards (40 CFR 191).

6.3.5.2 Description of the means used to produce the CCDF (see Table 6.3M).

6.3.5.3 Presentation of the CCDF (see Figure 6.3N) shows that the performance of the overall repository system satisfies the requirements of EPA standards concerning cumulative releases of radioactive material to the accessible environment.

6.3.5.4 Discussion of the uncertainties, both qualitative and quantitative, that bear on the CCDF (see Table 6.3O).

6.3.5.5 Alternative representations of the CCDF.

6.3.6 Model and Code Verification and Validation

A description of models and computer codes used to assess the cumulative releases to the accessible environment and the programs used to verify and validate them. See Table 6.3P.

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Section No. & Title: **6.3** **ASSESSMENT OF COMPLIANCE: CUMULATIVE RELEASE OF RADIOACTIVE MATERIALS**

Lead Author & Phone No. Scott Sinnock (Sandia)
W. J. Leonard (placeholder)
702-794-1821

A. Table No. **6.3A**

Title: **Screening Criteria for Processes and Events to Eliminate those that are Physically or Logically Unrealistic or are Expected to have Trivial Consequences**

Content: (See Section 6.3.1.1)

Criteria	Explanation
1. Probability	1. Probability of occurrence is less than 10^{-8}
2.	2.
3.	3.
4.	4.

[Table will be completed as per information, need ____.]

B. Table No. **6.3B**

Title: **Listing of Processes and Events Retained After Screening, Including those that may Materially Affect the Performance Assessment**

Content: (See Section 6.3.1.2)

Process/Event	Discussion/Impact
1. Process	1.
2. Event	2.
3. Process	3.
4. Event	4.

[Table will be completed as per information, need _____.]

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

Section No. & Title: **6.3** **ASSESSMENT OF COMPLIANCE: CUMULATIVE RELEASE OF RADIOACTIVE MATERIALS**

Lead Author & Phone No. Scott Sinnock (Sandia)
W. J. Leonard (placeholder)
(702) 794-1821

C. Table No. **6.3C**

Title: **Reasoned Explanation, Justified by Data, Demonstrating the Absence of Material Effect on Performance Assessment, for Processes or Events that have been Eliminated from Post-Screening Listing**

Content: (See Section 6.3.1.3)

Process/Event	Reasoned Explanation, Justified by Data
1. Process	1.
2. Process	2.
3. Process	3.
4. Event	4.

[Table will be completed as per information, need _____.]

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

Section No. & Title: **6.3** **ASSESSMENT OF COMPLIANCE: CUMULATIVE RELEASE OF RADIOACTIVE MATERIALS**

Lead Author & Phone No. Scott Sinnock (Sandia)
W. J. Leonard (placeholder)
(702) 794-1821

A. Figure No. **6.3A**

Caption: **Method Used for Forming Scenarios (Logic Flow)**

Content: (Reference 6.3.2.2.1)

B. Table No. **6.3D**

Title: **Criteria Used for Scenario Screening**

Content: (Reference 6.3.2.2.2)

Criteria Title	Explanation
1. Probability	1. Probability of occurrence is less than 10^{-6}
2.	2.
3.	3.

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Section No. & Title: **6.3** **ASSESSMENT OF COMPLIANCE: CUMULATIVE RELEASE OF RADIOACTIVE MATERIALS**

Lead Author & Phone No. Scott Sinnock (Sandia)
W. J. Leonard (placeholder)
(702) 794-1821

C. Table No. **6.3E**

Title: **List of Scenarios Retained in the Analysis after Completion of Screening**

Content: (References 6.3.2.2.3, 6.3.3.1)

Scenario	Discussion
1. Scenario 1	1.
2. Scenario 2	2.

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Section No. & Title: **6.3** **ASSESSMENT OF COMPLIANCE: CUMULATIVE RELEASE OF RADIOACTIVE MATERIALS**

Lead Author & Phone No. Scott Sinnock (Sandia)
W. J. Leonard (placeholder)
(702) 794-1821

A. Figure No. **6.3B**

Caption: **Cumulative Release of Radioactive Materials to the Accessible Environment - Scenario 1, Downward Movement of Water Through the Unsaturated Zone to the Saturated Zone and then Laterally to the Accessible Environment**

Content: (Reference 6.3.3.2)

B. Figure No. **6.3Ga through Gn**

Caption: **Cumulative Release of Radioactive Materials to the Accessible Environment - Scenarios 2 through n**

Content: (Reference 6.3.3.2)

C. Figure/Table No.

Caption/Title:

Content:

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Section No. & Title: **6.3** **ASSESSMENT OF COMPLIANCE: CUMULATIVE RELEASE OF RADIOACTIVE MATERIALS**

Lead Author & Phone No. Scott Sinnock (Sandia) (702) 794-1821

A. Table No. **6.3H**

Title: **Description of the Analytical Methods Used for Scenario Analyses**

Content: (See 6.3.3.3)

Analytical Method	Application and Remarks
Computer Code....	.....
Etc....	.....

B. Table No. **6.3I**

Title: **Probability of Occurrence of Each Process and Event Identified in 6.3.1 That Might Lead to a Significant Release of Radionuclides from the Overall System**

Content: (See 6.3.4.1, 6.3.4.5)

Process/Event	Probability of Occurrence	Uncertainty	Source
1. Process			
2. Process			
3. Event			

C. Table No. **6.3J**

Title: **Probability or Frequency of Occurrence Estimated for Each Scenario Identified in 6.3.2**

Content: (See 6.3.4.2)

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

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Section No. & Title: **6.3** **ASSESSMENT OF COMPLIANCE: CUMULATIVE RELEASE OF RADIOACTIVE MATERIALS**

Lead Author & Phone No. Scott Sinnock (Sandia)
(702) 794-1821

A. Table No. **6.3K**

Title: **Techniques Used to Estimate Probabilities and the Criteria Used for Each Technique**

Content: (See 6.3.4.3)

Technique Used	Criteria Used	Uncertainty	Source
1.Technique/Scenario	Criteria		
2.Technique/Scenario	Criteria		
3.Technique/Scenario	Criteria		

B. Table No. **6.3L**

Title: **How Time-Dependent Probabilities Have Been Assessed for Scenarios That Involve Transient Phenomena**

Content: (See 6.3.4.4)

Scenario	Explanation Regarding Time-Dependent Probability	Uncertainty	Source
1. Scenario			
2. Scenario			
3. Scenario			

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Section No. & Title: **6.3** **ASSESSMENT OF COMPLIANCE: CUMULATIVE RELEASE OF RADIOACTIVE MATERIALS**

Lead Author & Phone No. Scott Sinnock (Sandia)
W. J. Leonard (placeholder)
(702) 794-1821

C. Table No. **6.3M**

Title: **Means Used to Produce the Complementary Cumulative Distribution Function (CCDF)**

Content: (See 6.3.5.2)

Computer Code/ Model	Source	Resultant Output and Application

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Section No. & Title: **6.3** **ASSESSMENT OF COMPLIANCE: CUMULATIVE RELEASE OF RADIOACTIVE MATERIALS**

Lead Author & Phone No. Scott Sinnock (Sandia)
W. J. Leonard (placeholder)
(702) 794-1821

A. Figure No. **6.3N**

Caption: **Complementary Cumulative Distribution Function (CCDF)**

Content: (See 6.3.5.3)

B. Table No. **6.3O**

Title: **Uncertainties Bearing on the CCDF**

Content: (See 6.3.5.4)

Uncertainty	Discussion
1.	1.
2.	2.
3.	3.

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Section No. & Title: **6.3** **ASSESSMENT OF COMPLIANCE: CUMULATIVE RELEASE OF RADIOACTIVE MATERIALS**

Lead Author & Phone No. Scott Sinnock (Sandia)
W. J. Leonard (placeholder)
(702) 794-1821

C. Table No. **6.3P**

Title: **Verification and Validation of Computer Codes and Models Used to Assess the Cumulative Release to the Accessible Environment**

Content: (See 6.3.6)

Computer Codes/Model Used in Assessment	Computer Codes Used in Validation and Verification, with Simplifying Notes
1.	
2.	
3.	
4.	

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Form 3: References

Date 4/17/92

Section No. & Title: **6.3** **ASSESSMENT OF COMPLIANCE: CUMULATIVE RELEASE OF RADIOACTIVE MATERIALS**

Lead Author & Phone No. Scott Sinnock (Sandia)
W.S. Leonard (Placeholder)

Instructions: List all books, articles, or other references that are expected to be used for the section. Indicate whether references are draft or final and whether they are publicly available (i.e., published). Refer to the Writer's Guide, Appendix D of the Annotated Outline Management Plan for guidance on formatting reference information.

1. TBD

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Form A: Information Request

Date: 4/17/92

1. Log number:

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

3. Lead author & phone no: **Scott Sinnock (Sandia); W. J. Leonard (Placeholder) (702) 794-1861**

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

5. Work location:

6. Type of information needed:

7. What is the information needed for?

8. What group is the probable information supplier?

9. When is the information needed?

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:

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Form B: Information Response

Date 4/17/92

1. Section No. & Title: **6.3 ASSESSMENT OF COMPLIANCE: CUMULATIVE RELEASE OF RADIOACTIVE MATERIALS**

2. Person Supplying Information: Scott Sinnock (Sandia)
W.J. Leonard (Placeholder)
(702) 794-1821

3. Phone No.:

4. Lead Author (Requester):

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5. Response by Information Supplier:

Note: Attach additional sheets if necessary.

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

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Date: 4/17/92

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Lead Author:

Log. No.	Section	Date Issued	Date Response Received

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Section 6.4 Assessment of Compliance: Undisturbed Performance

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6.4 ASSESSMENT OF COMPLIANCE: UNDISTURBED PERFORMANCE 6.4-1

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6.4 ASSESSMENT OF COMPLIANCE: UNDISTURBED PERFORMANCE

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MGDS Annotated Outline Planning Package
Form 1: Text

Date 4/17/92

1. Section No. & Title: **6.4 ASSESSMENT OF COMPLIANCE: UNDISTURBED PERFORMANCE**

2. Lead Author & Phone No. Scott Sinnock (Sandia)
W. J. Leonard (Placeholder)
(702) 794-1821

3. First Phase Planning Package Due: 6/21/91

   Second Phase Planning Package Due: 10/18/91

   First Phase Skeleton Draft Due: 12/30/91

   Second Phase Skeleton Draft Due: 3/15/92

4. Plan Approved: W.R. Griffin 8/27/91
(Licensing Mgr & Lead Author)

5. Section Summary (Approximately 100 Words):

   This section provides an assessment, as required by EPA standards, of the predicted behaviors of the overall repository system (including a discussion of the uncertainties in these behaviors), when the system is not disrupted by human intrusion or the occurrence of unlikely natural events.

6. Opening Statement:

7. Main Body Outline: See attached.

8. Conclusion:

9. Support Authors & Their Assignments:

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

7. Main Body Outline (Continued)

6.4.0 Introduction

6.4.1 Individual Protection Requirements

This section contains a description of all potential pathways involved in the transport of radionuclides from the repository to members of the public residing in the accessible environment and the radiation dose rates projected to be received by those persons. This includes each scenario of "undisturbed performance" identified in 6.3.2 (see Tables 6.4A through An). Also identified are the concentrations of radionuclides in potential sources of drinking water (outside the controlled area) that might be obtained from a "significant source" of groundwater that has been contaminated by a release of radionuclides from the repository.

6.4.2 Ground Water Protection Requirements

This section identifies the concentrations of radionuclides in potential sources of drinking water that might be obtained from a "special source" of ground water that has been contaminated by a release of radionuclides from the repository. This includes each scenario of "undisturbed performance" identified in 6.3.2. Also identified are individual exposures that could result from ingestion of this water. (See tables 6.4B through Bn).

6.4.3 Model and Code Verification and Validation

This section contains a description of the models and computer codes used to assess the concentrations and dose rates in Sections 6.4.1 and 6.4.2 and the programs used to verify and validate them. (See Table 6.4C.)

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

Section No. & Title: **6.4 ASSESSMENT OF COMPLIANCE: UNDISTURBED PERFORMANCE**

Lead Author & Phone No. Scott Sinnock (Sandia)
W. J. Leonard (placeholder)

A. Table No. **6.4A through 6.4An**

Title: **Potential Pathways for Transport of Radionuclides from the Repository to Members of the Public Residing in the Accessible Environment**

Content: (See Section 6.4.1)

Scenarios 1 through n

Potential Pathways	Projected Dose Rate Received
1. Pathway	
2. Pathway	
.	
.	
n. Pathway to and identification of drinking water "significant source"	

B. Table No. **6.4B through 6.4Bn**

Title: **Concentrations of Radionuclides in Potential Drinking Water from "Special Sources" of Ground Water Contaminated by Radionuclide Release from the Repository**

Content: (See Section 6.4.2)

Scenarios 1 through n

"Special Source"	Concentration	Individual Potential Exposure
1. Source		
2. Source		

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C. Table No. **6.4C**

Title: **Models and Computer Codes Used to Assess Concentrations and Dose Rates**

Content: (Reference 6.4.3)

Model/ Computer Code	Used to Determine (Concentration/ Dose Rate)	Program Used to Verify/Validate
1. Model		
2. Model		
3. Code		

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MGDS Annotated Outline Planning Package
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Date 4/17/91

Section No. & Title: **6.4** **ASSESSMENT OF COMPLIANCE: UNDISTURBED PERFORMANCE**

Lead Author & Phone No. Scott Sinnock (Sandia)
W. J. Leonard (placeholder)

Instructions: List all books, articles, or other references that are expected to be used for the section. Indicate whether references are draft or final and whether they are publicly available (i.e., published). Refer to the Writer's Guide, Appendix D of the Annotated Outline Management Plan for guidance on formatting reference information.

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Form A: Information Request

Date: 4/17/92

1. Log number:

2. Section no. & title: **6.4 ASSESSMENT OF COMPLIANCE: UNDISTURBED PERFORMANCE**

3. Lead author & phone no: **Scott Sinnock (Sandia); W. J. Leonard (Placeholder) (702) 794-1861**

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

5. Work location:

6. Type of information needed:

7. What is the information needed for?

8. What group is the probable information supplier?

9. When is the information needed?

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:

MGDS Annotated Outline Information Need Form
Form B: Information Response

Date 4/17/92

1. Section No. & Title: **6.4 ASSESSMENT OF COMPLIANCE: UNDISTURBED PERFORMANCE**

2. Person Supplying Information: Scott Sinnock (Sandia)
   W. J. Leonard (placeholder)

3. Phone No.:

4. Lead Author (Requester):

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5. Response by Information Supplier:

Note: Attach additional sheets if necessary.

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Date: 4/17/92

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Section 6.5 10 CFR Part 60 Criteria

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6.5 10 CFR PART 60 CRITERIA 6.5-1

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6.5 10 CFR PART 60 CRITERIA

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REFERENCE

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MGDS Annotated Outline Planning Package
Form 1: Text

Date 2/21/92

1. Section No. & Title: **6.5** **10 CFR PART 60 CRITERIA**

2. Lead Author & Phone No. Scott Sinnock (Sandia)
W. J. Leonard (Placeholder)
(702) 794-1821

3. First Phase Planning Package Due: 6/21/91

   Second Phase Planning Package Due: 10/18/91

   First Phase Skeleton Draft Due: 12/30/91

   Second Phase Skeleton Draft Due: 3/15/92

4. Plan Approved: W.R. Griffin 8/27/91
(Licensing Mgr & Lead Author)

5. Section Summary (Approximately 100 Words):

   This section provides an assessment to demonstrate that site conditions present at the proposed repository are consistent with the performance objectives in 10 CFR 60.112 relating to isolation of waste.

6. Opening Statement:

7. Main Body Outline: See attached.

8. Conclusion:

9. Support Authors & Their Assignments:

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

7. Main Body Outline (Continued)

6.5.0 Introduction

6.5.1 Favorable Conditions

6.5.1.1 A summary of favorable conditions that are present at the proposed repository site. See Table 6.5A.

6.5.1.2 Demonstration that the favorable conditions are sufficient to provide reasonable assurance that the performance objectives in 10 CFR 60.112 relating to isolation of waste are met. This is accomplished by incorporating the favorable conditions into the conceptual models and descriptions of processes and events that could affect the repository (see Sections 6.2.2 and 6.2.3).

6.5.1.3 Description of how each favorable condition analyzed through incorporation into conceptual models and descriptions of processes and events, as indicated in Section 6.5.1.2 above, has been incorporated into a scenario of Section 6.3.2 or a model.

6.5.2 Potentially Adverse Conditions

6.5.2.1 A summary of potentially adverse conditions that are present at the proposed repository site. (see Table 6.5B).

6.5.2.2 For any potentially adverse condition which could significantly affect the ability of the repository to meet the objectives of 10 CFR 60.112 (and it cannot be demonstrated that the condition is compensated by favorable conditions and the condition cannot be remedied), the condition is incorporated into the conceptual design models and descriptions of processes and events that could affect the repository (see Section 6.3.1). The intent of 10 CFR 60.122 has been complied with through performance assessment results.

6.5.2.3 Description of how each potentially adverse condition which was analyzed as outlined in Section 6.5.2.2, above, was incorporated into a scenario of Section 6.3.2 or a conceptual model.

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MGDS Annotated Outline Planning Package
Form 2: Figures & Tables

Date: 4/17/92

Section No. & Title: **6.5 10 CFR PART 60 CRITERIA**

Lead Author & Phone No.

Scott Sinnock (Sandia)
W. J. Leonard (placeholder)
702-794-1821

A. Table No. **6.5A**

Title: **Summary of Favorable Conditions That Are Present at the Proposed Repository Site**

Content: (See Section 6.5.1.1)

Favorable Condition	Discussion - How 10 CFR 60.112 is Met
1. Zeolite screening	

B. Table No. **6.5B**

Title: **Summary of Potentially Adverse Conditions that are Present at the Proposed Repository Site**

Content: (See Section 6.5.2.1)

Potentially Adverse Condition	Significant Effect Regarding Ability of Repository to Meet 10 CFR 60.112
1.	1. No
2.	2. No
3.	3. No

C. Figure/Table No.

Caption/Title:

Content:

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Form 3: References

Date: 4/17/91

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Lead Author & Phone No.

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Form A: Information Request

Date: 4/17/92

1. Log number:

2. Section no. & title: **6.5 10 CFR PART 60 CRITERIA**

3. Lead author & phone no: **Scott Sinnock (Sandia); W. J. Leonard (Placeholder) (702) 794-1861**

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

5. Work location:

6. Type of information needed:

7. What is the information needed for?

8. What group is the probable information supplier?

9. When is the information needed?

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

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MGDS Annotated Outline Information Need Form
Form B: Information Response

Date: 4/17/92

1. Section No. & Title:

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3. Phone No.:

4. Lead Author (Requester): Marshall Weaver (702) 794-1871

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