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Site Characterization Plan

Yucca Mountain Site, Nevada Research and Development Area, Nevada

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Chapter 8, Section 8.0, Introduction

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8.0 INTRODUCTION

This chapter presents the Department of Energy's (DOE) plans for the site characterization program to be conducted at the Yucca Mountain site in the State of Nevada. Such a program is required by the Nuclear Waste Policy Act of 1982, by the regulations promulgated for geologic repositories by the U.S. Nuclear Regulatory Commission (NRC) in 10 CFR Part 60, and by the DOE's general guidelines for siting repositories, promulgated as 10 CFR Part 960. These legal requirements are summarized in the general introduction to this document, which also discusses the DOE's compliance with them.

This document represents the DOE's initial general plan for the Yucca Mountain site and is based on currently available information about the site and current concepts for the design of the repository and the waste package. This plan will be submitted to the NRC, as well as the Governor and the legislature of the State of Nevada. The DOE will make the plan available to the public and hold public hearings and briefings to receive comments. Because of these interactions, the DOE expects that the plans for site characterization at Yucca Mountain will be modified.

The DOE also expects to modify these plans as more information about the repository system becomes available. The data collected during site characterization will be used in the design of the repository and the waste package, as well as in the analyses of system performance. Characterization, design, and performance assessment activities will all be conducted during site characterization. These activities will depend on each other; for example, the data collected from the site will be used in designing the repository, while the design of the repository will be considered in determining the needed tests and analyses. The site characterization program will be modified, as needed, to meet newly developed design and performance requirements and in response to the data obtained from site characterization itself.

As site characterization proceeds, the results of investigations and any changes to plans will be reported to the NRC, the State of Nevada, and the general public through semiannual progress reports and technical reports. As the DOE revises its plans, it will do so in consultation with the NRC, the State of Nevada, and the general public. The DOE expects that this process will help to develop a consensus among the DOE, the NRC, the State of Nevada, and the general public that will lead to the early resolution of issues as part of the siting and licensing process.

The remainder of this introduction is devoted to two topics: the organization and content of Chapter 8 and the top-level strategy that describes the role the features of the site are expected to play in accomplishing the general objectives for the disposal system.

Organization and content of Chapter 8

Chapter 8, called Part B of the SCP, builds on the existing information about the site (the information that is reported in Chapters 1 through 5 of Part A) and on information about the conceptual designs of the repository and the waste package (the designs of the repository and the waste package are

described in Chapters 6 and 7 of Part A, respectively). The information presented in Part A not only summarizes the current technical knowledge about the site, but also constitutes part of the basis for defining the information that needs to be obtained during site characterization. Chapter 8 describes the DOE's plans for the characterization of the Yucca Mountain site.

The first three sections of Chapter 8 present the rationale for the site characterization program and develop from that rationale a detailed description of the tests to be conducted during the program. The discussion that follows describes the content of those sections.

The site characterization program has three principal purposes:

- To provide the data to be used to determine the suitability of a site.
- To provide the data needed for licensing.
- To provide the data for design of the repository and the waste package.

In planning a program to achieve these purposes, the DOE has adopted an approach that starts with the regulatory requirements that must be satisfied in siting and licensing the repository, identifies the performance and design information needed to address those requirements, and then develops specific investigations to obtain the needed information. This approach is embodied in an issue resolution strategy, which is discussed in some detail in Section 8.1. An important part of this strategy is an issues hierarchy (Section 8.1.1) that consists of key issues, issues, and information needs. The key issues and issues are based on the regulatory requirements that govern a repository. The information needs define the data and analytical techniques that are needed to resolve each issue. The DOE expects that satisfying the information needs will resolve the issues and that the resolution of the individual issues will lead to resolution of the key issues. Issue resolution is not likely to provide complete assurance that performance of the repository system will be acceptable. A reasonable assurance of acceptable performance is the general standard that will be met. The strategy described here and in Section 8.1 will be applied in an iterative manner to develop confidence throughout the licensing phases. The concept of reasonable assurance is discussed later in this section.

Another important part of the issue resolution strategy and the development of information needs for the issues is the "performance allocation" process, discussed in Section 8.1.2. Performance allocation consists of deciding which repository-system elements will be relied on in resolving an issue, identifying the functions that the elements will be expected to perform and the processes that will affect the performance of each element, making specific quantitative statements about the expected performance, and developing a testing program to obtain the needed information about the performance. The issue resolution strategy will guide the development of the programs for testing and analysis; it will help to make clear what tests and analyses are necessary. As the characterization of the site proceeds and more information becomes available, the strategy will be refined to support site selection and licensing.

Section 8.2 serves both as a summary of the overall strategy for resolving the issues and an introduction to the individual issues. It presents the issues to be resolved and their information needs. Section 8.3 then presents the complete strategies for issue resolution and describes the planned investigations to be conducted during site characterization. This section is organized into five sections around the major programs: site, repository, seals, waste package, and performance assessment.

The site program is discussed in Section 8.3.1. Organized by technical disciplines, this section describes the investigations, studies, and activities to be carried out to resolve the design and performance issues in the issues hierarchy. The site program is designed to reduce uncertainty about site properties and conditions and to reduce uncertainty in the conceptualization of the site physical system. Systematic hypothesis testing is being used to discriminate between alternative conceptual models by eliminating untenable or nonviable hypotheses.

The repository program is described in Section 8.3.2, which provides detailed resolution strategies for the repository design issues. The section identifies the site information and the design activities needed for issue resolution.

The seal program is covered in Section 8.3.3, which identifies the activities required to develop designs and demonstrate the performance of seals to be placed in shafts, ramps, drifts, and boreholes.

The waste package program is discussed in Section 8.3.4. This section presents the detailed issue resolution strategies for the issues that deal with the design of the waste package. The section identifies the site information and the design activities needed for issue resolution.

Section 8.3.5 presents the performance assessment program. Strategies to address the preclosure and postclosure performance issues and discussions of the analytic techniques needed for the safety and performance assessments for these strategies are presented. The section identifies the site information and the performance assessment activities needed for resolving the issues.

Much of the information presented in Section 8.3 is summarized in performance allocation and hypothesis testing tables. A careful study of these tables will provide an understanding of the information to be provided by the site program and the intended use of this information for resolving the design and performance issues.

The plans for surface-based activities and for subsurface excavations related to implementing the site characterization program described in Section 8.3 are presented in Section 8.4. This section also discusses the potential impacts on the integrity of the site as a result of conducting these activities. Section 8.4 is divided into three parts. The first section, 8.4.1, presents background information on the approach adopted by the DOE to guide the characterization program, gives the approach to incorporating the requirements of 10 CFR Part 60 into the development of the testing program, and discusses the concepts of flow in the unsaturated zone. The rationale for the planned testing is presented in Section 8.4.2, which

also describes the surface testing and the underground test facility and evaluate whether construction or operation of facilities or the conduct of the tests is likely to adversely impact the results of site characterization activities. Section 8.4.3 evaluates the impact of the testing program on the integrity of the site by considering its potential impacts on the postclosure performance objectives.

Section 8.5 presents the major milestones, decision points, and summary schedule information established for the site characterization program through the submittal of the license application to the NRC. This section summarizes the schedule information provided in Section 8.3. The schedule information provided in both Section 8.3 and 8.5 represents a snapshot in time with regard to planned activities and their schedules. Schedules will be reevaluated and updated as the site characterization program proceeds.

Top-level strategy

This section presents the "top-level strategy," that is, a brief explanation of the role the features of the Yucca Mountain site are expected to play in achieving the general objectives for the system. As a consequence of this role, which will be explained, the program for characterizing the site places considerable emphasis on the range of expected flow conditions in the unsaturated rocks in which the waste would be emplaced. The program also emphasizes the geochemistry and other characteristics of the unsaturated rocks. These characteristics could affect performance of the waste packages and radionuclide transport through the unsaturated rocks. In addition, the geohydrology of the saturated rocks deep beneath the site will be characterized. Reliance on these features requires the investigation of any disruptive processes and events that might alter the features. The top-level strategy also emphasizes pre-closure radiation safety and the effects of seismicity on the surface and underground facilities. This section discusses the basis for the emphasis on these features in the site characterization program.

The principal role of a disposal system is to isolate waste for a long period into the future. Therefore, the general objective for the entire system is to limit any radionuclide releases to the accessible environment. This objective will be achieved by selecting a site that contains natural barriers against radionuclide releases and by providing an appropriate system of engineered barriers. To provide additional insurance that the system will perform adequately, individual objectives have also been defined for the engineered and natural barriers to radionuclide release and for the design of the disposal system. The general objective for the engineered barriers is that they should limit the release of radionuclides to the natural barriers. The general objective for the natural barriers is that the time of travel of significant quantities of radionuclides through these barriers to the accessible environment should be very long. In particular, since ground water may transport radionuclides, the ground-water travel time should be very long. The general objectives for the design of the disposal system are that its operation should be safe and that its construction should not compromise its ability to meet the other general objectives.

These general objectives are compatible with the regulations promulgated by the NRC in 10 CFR Part 60. In the regulations, the NRC specifies postclosure performance objectives, including the environmental standards anticipated to be set by the Environmental Protection Agency for releases to the accessible environment, individual protection, and ground-water protection; requirements on the containment to be provided by the set of waste packages and on the rate of release of radionuclides from the engineered-barrier system; and an objective for the pre-waste-emplacement ground-water travel time. The regulations also specify design criteria for the disposal system to ensure the postclosure performance objectives would be met, and they set preclosure objectives for radiation protection. Detailed strategies that explicitly address the NRC regulations are presented in Sections 8.1, 8.2, and 8.3. The remainder of this section describes the top-level strategy to address the general objectives for the disposal system.

General objective for the disposal system

The major system elements that are expected to affect waste isolation at the Yucca Mountain site can be seen in Figure 8.0-1. As explained in detail in Chapter 3, the currently available information suggests that only small amounts of water are available to percolate slowly downward through Yucca Mountain. If the Yucca Mountain site is developed for a repository, water that moves through the unsaturated rock above the repository could continue down to the unsaturated rock unit in which the underground repository would be constructed. If any of this water could reach the emplaced waste, it might dissolve radionuclides and carry them in solution through the unsaturated rock below the repository to the saturated rock that underlies the unsaturated zone. After reaching saturated rock (Figure 8.0-1), the water joins the much larger, horizontal flow there. Radionuclides that are carried by the water could therefore be transported by the flow in the saturated zone and move toward the accessible environment.

To reach the emplaced waste, the water would have to penetrate the engineered-barrier system. For the purposes of defining the top-level strategy, the major elements of this system are the container and the waste form inside the container. There would also be an air gap between the container and the wall of the borehole in which the container would be emplaced.

This sequence of events--downward water movement, water penetration into the engineered-barrier system, downward transport of radionuclides to saturated rock, and horizontal transport--provides a way by which radionuclides could move from the Yucca Mountain repository to the accessible environment. According to the available evidence, the percolation flux at and below the repository horizon is very low. Furthermore, it appears that the percolation of water through the unsaturated rock units at this depth is primarily in the rock matrix rather than through fractures. If the water is retained within the rock matrix, as it appears to be, the water would not be expected to move from the rock across the air gap to the waste container; the water would, therefore, not be expected to reach the waste. Furthermore, the results of preliminary studies have suggested that the quantity of moving water is so small that any corrosion of the disposal container and dissolution of radionuclides would be limited even if the water could cross the air gap. The evidence also suggests that the movement of water in the rock matrix is very slow and that, therefore, the transport of any radionuclides dissolved in

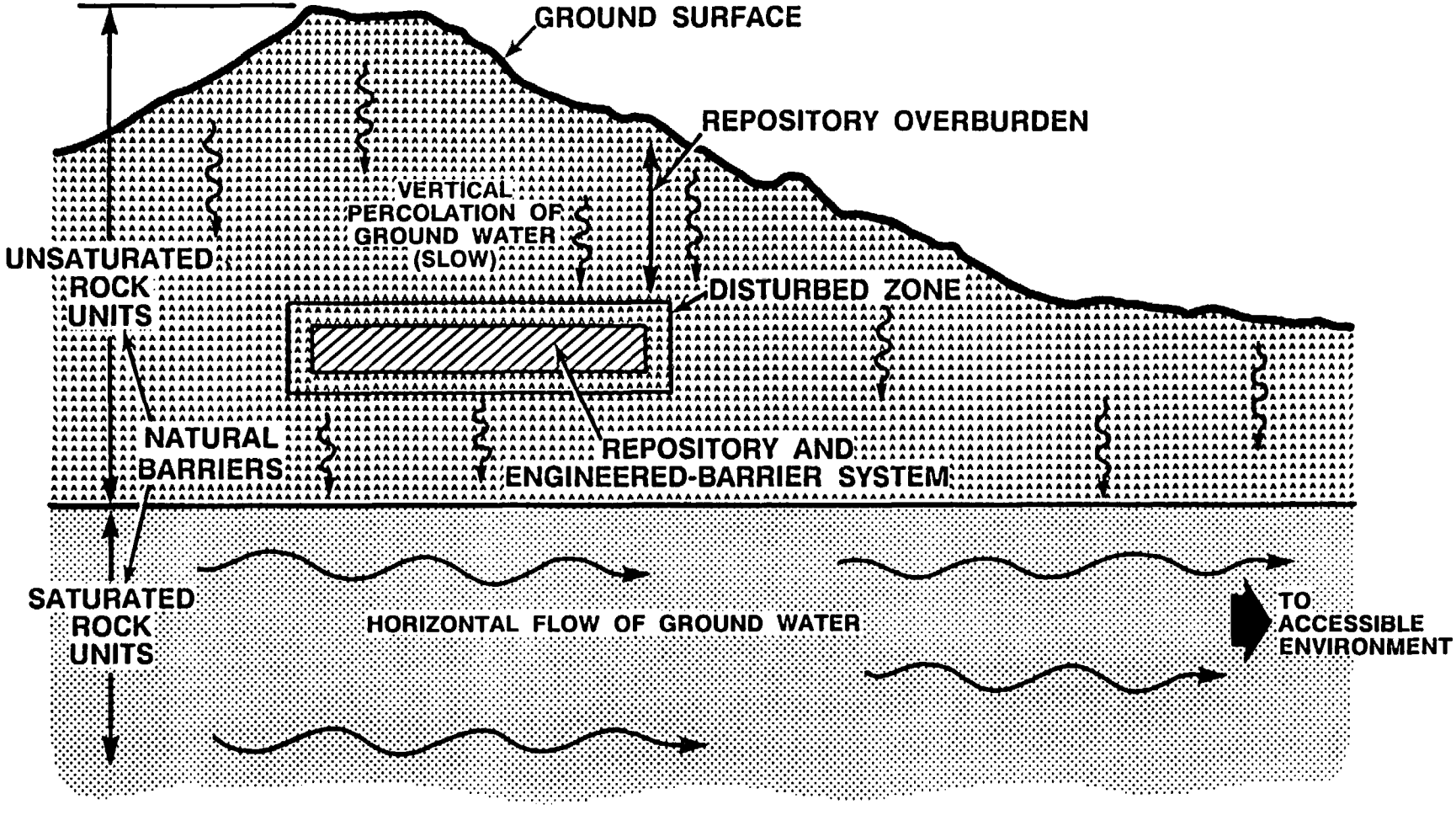

Figure 8.0-1. Major system elements expected to affect waste isolation at the Yucca Mountain site.

this water downward through the unsaturated rocks below the repository would be very slow. An additional characteristic of the unsaturated rock and the water is their geochemistry, which will determine the radionuclide dissolution and the retardation of radionuclide transport.

Therefore, the elements of the system that the DOE will investigate in the site characterization program to evaluate the system with respect to the general objective are

- The unsaturated rock units.
- The saturated rock that lies below the unsaturated rock.
- The engineered-barrier system.

Concentrating on the characteristics of only one of these features, such as the slow movement of water through the unsaturated rocks below the repository, could reduce the cost of the site characterization program. The DOE has decided, however, that it is prudent to consider initially the characteristics of all three of these features. Future evidence may show, for example, that the current estimates of ground-water travel time are too long. If so, the DOE's strategy may need to focus on the other features. Choosing all of these features is a way of dealing with the uncertainties in each of them; it ensures that the site characterization activities, guided by the strategy, will collect the data needed to evaluate the site with respect to the general objective. Analyses conducted during site characterization may indicate that other features may need to be considered as well. Conversely, information obtained during site characterization may show that fewer features need to be taken into account. In either case, the top-level strategy can be revised appropriately.

One further sequence of events might contribute to a release under the current conditions at Yucca Mountain. If the waste containers were breached, radionuclides that exist in the waste in gaseous form might move upward through the air spaces in the unsaturated rock above the repository. They might then reach the accessible environment at the ground surface above the repository. The available information is not complete enough to decide definitively whether this sequence is capable of producing significant releases. It is not clear, for example, that the waste form can release gaseous radionuclides rapidly enough or in sufficient quantities to be important. The DOE will evaluate the potential for gaseous release to determine the significance of this mode of release. The elements of the system that may affect gaseous releases at the site are the unsaturated rock above the repository and the engineered-barrier system. The current evidence is not sufficient to indicate if the unsaturated rock would be effective. The available evidence does suggest, however, that the waste form is likely to allow only negligible amounts of volatile radionuclides to escape. The top-level strategy, therefore, focuses primarily on the ability of the engineered-barrier system to limit the rate of release of gaseous radionuclides.

General objective for performance of the engineered-barrier system

The general objective for the engineered-barrier system is to limit release of radionuclides to the natural barriers. In the top-level strategy, the DOE has chosen to focus on three particular components to evaluate the performance of the engineered-barrier system.

- The air gap between the container and the host rock.
- The container.
- The waste form.

The container is expected to provide the principal barrier to the release of radionuclides from the engineered-barrier system. This barrier will be designed to provide substantially complete containment of the wastes during the early period when the heat and radiation emitted by the waste are at their peak. The limited availability of water in the unsaturated zone is expected to contribute to the ability of the container to limit the release of radionuclides to the natural barriers. In addition, the container materials will be chosen to be compatible with the geochemistry of the water in order to limit degradation of the containers in contact with any water.

The air gap between the container and the host rock is expected to increase the ability to limit the release of radionuclides. That is, because the percolation flux is expected to be low and because the water is expected to be retained in the rock matrix, little water would be available to leave the rock and cross this air gap. Therefore, the amount of water available to contact the waste packages is expected to be even less than the small amount in the host rock.

The waste form is chosen as an additional barrier to limit the rate of radionuclide release from the engineered-barrier system. Because of the low probability of early container failure and because of the small quantities of water available for waste-form dissolution and the leaching of radionuclides, the spent fuel or glass matrix is expected to limit the rate of release.

General objective for the performance of the natural barriers

As explained above, one natural barrier within the geologic setting that can contribute to the isolation of the waste and to the overall system performance is the long ground-water travel time to the accessible environment. The DOE has chosen to focus on two barriers to determine the ground-water travel time:

- The unsaturated rock units below the repository.
- The saturated rock below the unsaturated rock.

The current evidence suggests that the travel time from the repository through the unsaturated units to the saturated zone is longer than 10,000 yr. Furthermore, many of the radionuclides important for waste isolation will have an even longer travel time than the ground water because of geochemical and mechanical retardation processes. Therefore, these units are expected to provide an effective barrier to radionuclide transport. According to the available evidence, the saturated rock units can add at least a few hundred years and possibly a few thousand years to the total time that radionuclides would take to move to the accessible environment.

General objectives for the design of the disposal system

The general design objectives to ensure safe operation without compromising the ability to meet the other general objectives have a number of implications for the site characterization program. In particular, the

surface and underground facilities must be designed to withstand potential ground motion or surface rupture at the site. The available evidence suggests that the design can accommodate the range of seismic activity expected at the site. Information regarding the expected frequency and magnitude of earthquake-related activity at the site will be needed to support the detailed design.

The design of the repository system must also address radiation protection of the surface and underground facilities. It is expected that standard techniques will be adequate to assess preclosure radiation safety. Although these assessments will not rely heavily on features of the site, some investigations will be conducted to support them.

Priorities for the site characterization program

Priorities for the testing program can be inferred from the choices made for the top-level strategy, that is, the elements identified and the expected role of these elements with regard to the general objectives suggest the priorities for the investigations in the site characterization program. The top-level strategy to address these objectives at the Yucca Mountain site leads to the following areas of emphasis:

- Unsaturated-zone flow characteristics.
- Site characteristics (e.g., geochemistry) affecting performance of the container and the waste form and transport of the radionuclides in the unsaturated zone and the geohydrologic characteristics of the saturated rocks that underlie the unsaturated zone.
- Unlikely processes or events that disturb site characteristics.
- Preclosure radiation safety and the effects of seismicity on the surface and underground facilities.

The top-level strategy focuses strongly on the investigations of the characteristics of the flow in the unsaturated zone, relying heavily on the current view that the percolation flux is low and that the water in the unsaturated zone is tightly confined within the rock matrix. If these concepts can be confirmed, then the general objective for the system and for the postclosure performance of the engineered and natural barriers are very likely to be met. Therefore, the investigations of these concepts have the highest priority in the program. As part of these investigations, the program will address alternative concepts including flow in fractures, lateral movement of water at rock interfaces in the unsaturated zone, and the effect on the flow of structural features such as faults. The ability of the unsaturated rock to hold water and limit contact of water with the waste packages will also be investigated.

Because of uncertainties in these concepts and to add confidence that the general objective will be met, other site characteristics will also be investigated. The top-level strategy also places emphasis on other characteristics of the site as discussed above. Therefore, at a somewhat lower level of priority, the program will give attention to the geochemistry and other characteristics of the unsaturated rocks that may affect the perform-

ance of the waste packages and the transport of radionuclides in the unsaturated rocks and the geohydrology of the saturated rocks deep below the site.

The design of the repository system must address preclosure concerns such as the effect of seismic activity. Accordingly, an extensive program to investigate seismicity affecting the site is planned. This program will evaluate the probability and magnitude of ground motion and potential surface rupture at the Yucca Mountain site.

The site characterization program must also address those processes and events that might occur in the future and disrupt the site characteristics important to waste isolation. For example, the possibilities for extreme climatic changes or faulting will be investigated to evaluate effects on percolation, local flux, and the altitude of the water table in relation to the repository horizon. The probability of occurrence and the potential effects of volcanism on the characteristics of the site will also be investigated. The following is a general list of the disruptive processes and events that present data suggest are sufficiently credible to warrant consideration:

1. Extreme climate change.
2. Stream erosion.
3. Faulting and seismicity.
4. Magmatic intrusion.
5. Extrusive magmatic activity.
6. Extensive irrigation.
7. Intentional ground-water withdrawal.
8. Exploratory drilling.
9. Resource mining.
10. Climate control.
11. Surface flooding and impoundments.
12. Regional changes in tectonic regime.
13. Folding, uplift, and subsidence.

This description of the general priorities that the top-level strategy leads to serves primarily as a broad introduction to the detailed discussions in Sections 8.1. through 8.5. Readers who wish to understand fully the planned investigations and the reasons for them must consult those sections, which provide complete strategies, derive investigation plans from the strategies, and explain the investigations in detail.