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(Section 113)

Consultation Draft

Site Characterization Plan

Reference Repository Location, Hanford Site, Washington

Volume 9

January 1988

U.S. Department of Energy
Office of Civilian Radioactive Waste Management
Washington, DC 20585

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SITE CHARACTERIZATION PLAN

Chapter 8 - SITE CHARACTERIZATION PROGRAM

Section 8.3.5

Performance Assessment Program Plan

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8.3.5 PERFORMANCE ASSESSMENT PROGRAM PLAN

The plan described in this section establishes a framework for conducting performance assessment analyses for the Hanford Site as an element of the Basalt Waste Isolation Project (BWIP) conducted by the U.S. Department of Energy (DOE). Performance assessment is defined as those analyses conducted to assess the suitability of a site for disposing of high-level nuclear wastes. Performance assessment generally encompasses the quantitative evaluations related to issue resolution and licensing strategies (see Section 8.2.2). As such, performance assessment activities constitute a major segment of the issue resolution process governing project activities.

Performance assessment includes evaluating both the preclosure period during construction, operation and monitoring, and decommissioning and the postclosure period. During the repository preclosure period, performance assessment is synonymous with safety assessment. Postclosure assessments will focus principally on the 10,000-yr interval following closure, but some will extend to 100,000 yr.

This section outlines the plan for evaluating the preclosure and postclosure performance of subsystems and the overall geologic repository system. More detailed plans for evaluation of repository subsystems are described in Sections 8.3.1 through 8.3.4. The broad plans described in this document will be complemented as needed by detailed study plans for analyses supporting major design and licensing activities.

The preclosure safety assessment strategy discussed in Section 8.3.5.1 will ensure that exploratory shaft and repository facility design, construction, operation, and decommissioning comply with applicable radiological and other safety performance objectives. Preclosure safety assessment is a major component of the overall licensing strategy of Key Issue 2 and involves assessment of the risks and hazards to which the repository workers and the general public may be exposed as a result of the activities that will be carried out at the repository prior to permanent closure. Each phase of repository design will be evaluated with respect to the health and safety of operating personnel and the public. Preclosure safety assessments will also perform the following:

- Investigate avoidance and (or) mitigation measures.
- Study the potential for conflicts among competing safety objectives.
- Provide information for design decisions.

The results from preclosure safety assessments will be input directly into the design activities on a continuous basis.

The postclosure performance assessment strategy discussed in Section 8.3.5.2 will evaluate the long-term performance of the repository. This evaluation will employ computer simulations of the phenomena important to the release and transport of radionuclides. In accordance with guidance

outlined in the Draft Generic Technical Position on Licensing Assessment Methodology for High-Level Waste Geologic Repositories (NRC, 1984), the methodology for postclosure performance assessment will emphasize the development and use of models that (1) are judged to be complete and adequate through peer review processes, (2) express results in terms that depict data and model uncertainties, and (3) represent the range of conceptual models that can be reasonably inferred from the available data.

Important steps in the performance assessment process include the development and improvement of conceptual models, the development and application of numerical models (i.e., the quantitative representations of the conceptual models), and the documentation and testing of these models. Many of the variables in the simulation models will be expressed in terms of probability distributions to reflect the uncertainties in these variables due to uncertainties in the data and in the interpretation of the data. This approach will permit analytical results to be given in probabilistic terms. The probability distributions for model input parameters represent either a statistical expression of experimental data or an expression of expert subjective judgments. Analyses will be performed at both the repository system and subsystem levels of investigation. In addition to these analyses, parametric and sensitivity analyses will be performed to identify important parameters and quantify parameter and model uncertainty. The results from these analyses will be used to define and prioritize data needs. As such, the principal objectives of postclosure performance assessment are as follows:

- Assess the long-term performance of the system and subsystems relative to regulatory performance requirements.
- Guide data collection and design activities.

As a major facet of postclosure performance assessment, conceptual and numerical models must be developed to assess the long-term (10,000 yr) behavior of the repository subsystems. These subsystem assessments must then be integrated into a unified evaluation of the performance of the overall repository system. Plans for these subsystem and system assessments, and their relationship to resolving related key issues and performance issues, are presented in Section 8.3.5.2.

Section 8.3.5.3 describes the activities needed for ensuring that sufficient information is obtained to demonstrate the resolution of all issues and thereby to demonstrate either that the system will comply or cannot comply with applicable preclosure and postclosure regulations.

Section 8.3.5.4 describes the mathematical models and computer codes already substantially developed for postclosure performance assessment and currently slated to be used for license application. Section 8.3.5.5 describes models and codes that still require significant development for use in analyses to support the license application. Both sections also discuss methods to quantify expert judgment as a major element in the process for evaluating repository performance.

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8.3.5.1 Strategy for preclosure safety assessment

Preclosure safety assessment is required by U.S. Nuclear Regulatory Commission (NRC) regulations as part of license application and also provides a mechanism for resolving Key Issue 2. Key Issue 2 addresses the potential for radiological exposure of repository personnel and the public during the preclosure period (see Section 8.2.2). The preclosure safety assessment is used to (1) provide guidance to design by determining the need for preventive measures for accident avoidance and mitigative measures for reducing the effects of potential accidents; (2) provide guidance to improve and (or) modify repository operating procedures; (3) demonstrate the compliance with regulatory requirements in 10 CFR 60 (NRC, 1987a), 40 CFR 191 (EPA, 1986), and 10 CFR 960 (DOE, 1987a); (4) identify the structures, systems, and components important to safety for supporting identification of Q-list items; (5) support the final site selection process by providing consistent preclosure safety assessment results for site comparisons; and (6) provide information to the general public on preclosure repository safety.

The general categories of risks that will be considered within the scope of preclosure safety assessments include: the radiation effects on repository personnel and the public from accidents and routine operations, the nonradiological effects on repository personnel and the public from accidents and routine operations, and the economic costs of accidents. For the resolution of Key Issue 2, however, only radiological safety will be considered. Nonradiological safety assessment and economic costs due to accidents will be considered for the resolution of Key Issue 4. The economic analyses will not address costs due to perceived risks. Socioeconomic concerns will be considered under Key Issue 3, whose issues will be identified after the environmental impact statement scoping hearings (DOE, 1987b). The preclosure safety assessment will address risks during the following preclosure activities:

- Construction of surface facilities and subsurface excavations.
- Emplacement, including the (1) receipt, handling, and preparation of spent fuel and other wastes in surface facilities for emplacement; (2) emplacement of wastes in the underground facility; (3) testing and inspection activities; and (4) monitoring and maintenance activities before the repository is permanently closed.
- Retrieval operations (if required).
- Decommissioning activities, including the removal of the surface facilities and the permanent sealing of underground facilities.

The U.S. Department of Energy (DOE) plans to include many types of safety analyses within the overall structure of the analytical techniques of safety assessment. For the analyses performed by the repository projects, the DOE is developing a Preclosure Risk Assessment Methodology (PRAM) that will establish common procedures for assessment methods, computer codes, assumptions, and data

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bases. Section 8.3.5.1.1 overviews the PRAM, Section 8.3.5.1.3 covers the uses of the PRAM for radiological accidents, and Section 8.3.5.1.4 covers the applicability of the PRAM to routine operations.

8.3.5.1.1 Overview of Preclosure Risk Assessment Methodology Program

An overview of the PRAM program is illustrated in Figure 8.3.5-1. The program addresses four categories: (1) major considerations for performing a preclosure safety assessment, (2) analytical approaches for assessing safety, (3) safety assessment results, and (4) end uses of the preclosure safety assessment (see Fig. 8.3.5-1). The PRAM program will further develop and refine the safety assessment process as the program progresses. The PRAM program will address the spectrum of risk categories, the Office of Civilian Radioactive Waste Management uses of the safety assessment results, and the data needed for assessing repository safety.

The PRAM program will also address analytical methods to be used during the advanced conceptual design and license application design and will further develop the important-to-safety aspect of the Q-list Methodology. This important-to-safety aspect of Q-list Methodology has been established for the conceptual design.

The methods to evaluate the risks of various preclosure operations will also be considered by the PRAM program. The preclosure operations include construction, emplacement, potential retrieval, and decommissioning. The spectrum of risk categories that may be considered includes the following:

- RAP - Radiological risk from accidents to the public.
- RAW - Radiological risk from accidents to the essential workers.
- RRP - Radiological risk from routine operations to the public.
- RRW - Radiological risk from routine operations to the workers.
- NAP - Nonradiological risk from accidents to the public.
- NAW - Nonradiological risk from accidents to the workers.
- NRP - Nonradiological risk from routine operations to the public.
- NRW - Nonradiological risk from routine operation to the workers.
- COSTR - Economic risk from radiological accidents.
- COSTN - Economic risk from nonradiological accidents.

For resolving issues related to regulatory requirements for siting and licensing, this document addresses the RAP, RAW, RRP, and RRW risk categories. Nevertheless, the PRAM program will address the appropriate risk categories necessary to meet the needs of the end users (see Section 8.3.5.1). The applications of the risk categories to the various Office of Civilian Radioactive Waste Management end uses are shown in Figure 8.3.5-2.

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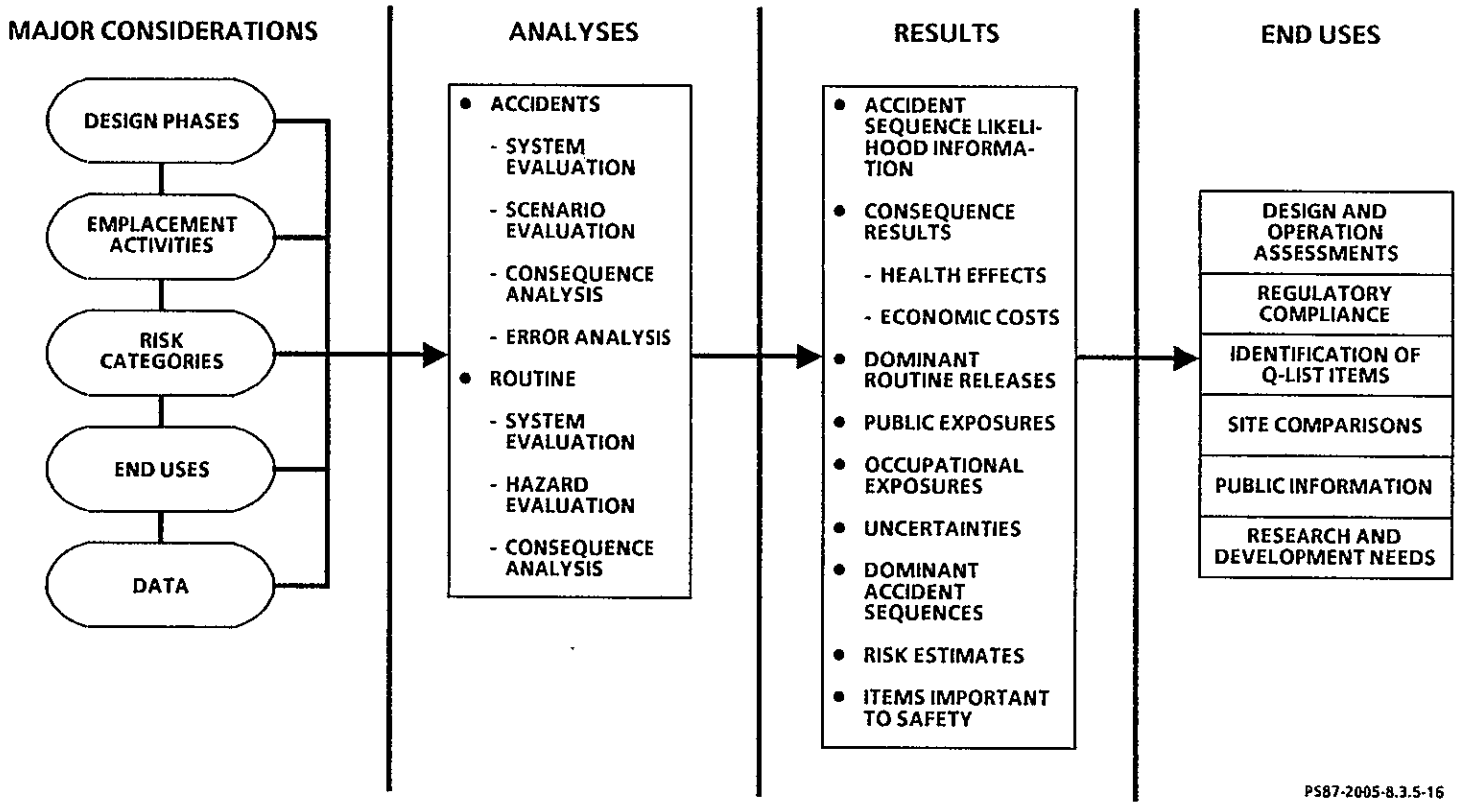

Figure 8.3.5-1. Overview of Preclosure Risk Assessment Program.

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End uses	RAP	RAW	RRP	RRW	NAP	NAW	NRP	NRW	COSTR	COSTN
Design and operations assessment	X	X	X	X	X	X	X	X	X	X
Regulatory compliance	X	X	X	X		X		X		
Identification of Q-list items	X									
Site comparisons	X	X	X	X	X	X	X	X	X	X
Public information	X	X	X	X	X	X	X	X	X	X
Research and development needs	X	X	X	X	X	X	X	X	X	X

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NOTE: RAP = Radiological risk from accidents to the public.
RAW = Radiological risk from accidents to the workers.
RRP = Radiological risk from routine operations to the public
RRW = Radiological risk from routine operations to the workers.
NAP = Nonradiological risk from accidents to the public.
NAW = Nonradiological risk from accidents to the workers
NRP = Nonradiological risk from routine operations to the public
NRW = Nonradiological risk from routine operations to the workers
COSTR = Economic risk from radiological accidents.
COSTN = Economic risk from nonradiological accidents.
//// = Used for resolving preclosure radiological safety assessment issues (Key Issue 2)

Figure 8.3.5-2. Application of risk categories to end uses.

The purpose of the PRAM program is to produce the results to support the various Office of Civilian Radioactive Waste Management activities. The results include (1) accident sequence likelihood information, (2) consequence results including health effects and economic costs, (3) information on dominant routine releases, (4) public and occupational exposures, (5) items important to safety, (6) estimates of the uncertainties in the safety assessment results, (7) dominant accident sequences from each repository operation activity, and (8) risk estimates. The PRAM program will further define the results for supporting each end use.

Section 8.3.5.1.3 describes the analytical approach that will be used to assess radiological risks from accidents. Section 8.3.5.1.4 describes the approach that will be used to assess radiological risks from routine operations. One of these approaches will be applied to each of the risk categories listed previously. The PRAM program will refine the two general analytical approaches for application to the risk categories addressed in this document.

A general description of the types of radiological and nonradiological risks that are expected to result from accidents and routine operations during repository construction, operation, retrieval, and decommissioning are briefly summarized in the following paragraphs. Preliminary evaluations of risks from some of these categories are contained in the environmental assessment for the BWIP site (DOE, 1986a).

8.3.5.1.1.1 Construction

8.3.5.1.1.1.1 Accidents.

Because no significant quantities of radioactive materials will be present at the site during construction (radioactive materials may include radiographic camera sources), no significant radiological effects from accidents are expected. Accidents during construction of the surface facilities should be typical of any large construction project and will primarily affect the workers. Some public effects are possible from construction accidents, but these would principally be associated with the transportation of construction materials. Accidents during construction of the mined portion of the repository should be typical of any large underground construction project.

8.3.5.1.1.1.2 Routine operations.

Routine nonradiological risks associated with construction of the surface portions of the repository are relatively limited and are typically characterized as part of an environmental assessment. Preliminary estimates of the types and amounts of natural radioactivity and dusts that would be present in the mine have been made and should be typical of any large underground construction project. Large amounts of the host rock material will be stored on the surface during the construction and operational phases of the repository. This practice may result in releases of constituents of the host rock to either the atmosphere, by wind action, or to the groundwater, by leaching. In addition, small quantities of radioactive material will be used during construction for nondestructive testing.

8.3.5.1.1.2 Emplacement

8.3.5.1.1.2.1 Accidents.

Radiolcgical risks to the public from accidents during plant operations are traditionally addressed in safety assessment studies. These accidents can affect both workers and the public. Small "industrial" accidents could expose workers to both radiological and nonradiological hazards.

8.3.5.1.1.2.2 Routine operations.

Workers will receive routine radiological doses from handling the radioactive wastes that are received at the surface facility. Small amounts of radioactive material may be released as routine effluents from the facility at levels within regulatory levels. There may also be small releases of fugitive dust from mined material stored at the surface.

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8.3.5.1.1.3 Retrieval

8.3.5.1.1.3.1 Accidents.

Retrieval is also considered a preclosure activity. Risks of accidents during retrieval will be characterized using methods similar to those applied to estimate risks from the emplacement activity of the repository. (Retrieval may be more complicated than emplacement because of the potential for degradation of the waste container, borehole, and drifts.)

8.3.5.1.1.3.2 Routine operations.

Risks of routine operations during retrieval will be characterized using methods similar to those applied to estimate risk during emplacement. (Again, retrieval may be more complicated than emplacement.)

8.3.5.1.1.4 Decommissioning

8.3.5.1.1.4.1 Accidents.

Radiological risks from accidents during decommissioning are expected to be small because only small amounts of residual radioactive material are expected to be in the surface facilities. Nonradiological accident risks during decommissioning should be similar to nonradiological risks from accidents during construction.

8.3.5.1.1.4.2 Routine operations.

Workers will be exposed to low levels of radiation routinely during the decommissioning operations and could be exposed to dust and other potential nonradiological hazards. Routine offsite effluents are expected to be small.

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8.3.5.1.2 Identifying information needs

Conducting an assessment of the risk categories (see Sections 8.3.5.1 and 8.3.5.1.1) requires a great deal of information (e.g., physical property values, design descriptions and objectives, and analytical tools). The approach used to develop the resolution strategies for Issues 2.1 through 2.5 provides a comprehensive and systematic process for determining these information needs.

As a result of the issue resolution process, the majority of information needs are associated with the design of engineered systems. These systems do not require site characterization, environmental monitoring, or socioeconomic monitoring activities. Instead, the parameter goals and expected ranges for these design-related parameters will be developed as an integral part of the normal design and safety assessment process. For those information needs that require site characterization, the parameter attributes that will be measured

and the methods of satisfying the information needs are contained in study plans appropriate for the discipline or subject area of interest, as discussed in Sections 8.1 and 8.3.1 through 8.3.4. For those information needs requiring the collection of environmental or socioeconomic data, the parameter attributes that will be measured and the methods of satisfying the information needs will be handled by the environmental and socioeconomic program.

8.3.5.1.3 General analytical approach for assessing radiological risks from accidents

The general analytical approach for the assessment of radiological risks from accidents to the public and workers is illustrated in Figure 8.3.5-3. Preclosure safety assessment can be performed at any design phase (e.g., conceptual design, advanced conceptual design, and license application design). However, its specificity is clearly a function of the level of detail of the design and operations information. The analytical steps are briefly described below, and their results are applicable to risk categories RAP and RAW (see Section 8.3.5.1.1 for category descriptions). The appropriate analytical steps and the depth of analysis of each step at each design assessment phase will depend on the design and operations information, the available analytical data, and the intended end use.

8.3.5.1.3.1 Step 1--Repository familiarization and identification of initiating events

This step will identify and describe the physical configurations and processes of the repository systems and support systems to be modeled and the dependencies among them. In addition, the accident-initiating events to be considered in the risk assessment will be identified. A description of the system includes the following information:

- Surface and underground facility layout.
- Engineering diagrams (e.g., process flow, functional, piping and instrumentation, and component status during standby, operation, maintenance, and emergency shutdown).
- Operating procedures.

The information gained from this step will be used to model the repository systems and support systems in Step 3.

After describing the repository systems and support systems, the potential accident-initiating events that could challenge the equipment and operation of the repository are identified. The initiating events will be identified based on previous studies, site characterization activities, and a detailed examination of the repository design and activities performed during construction, emplacement, retrieval, and decommissioning. The initiating

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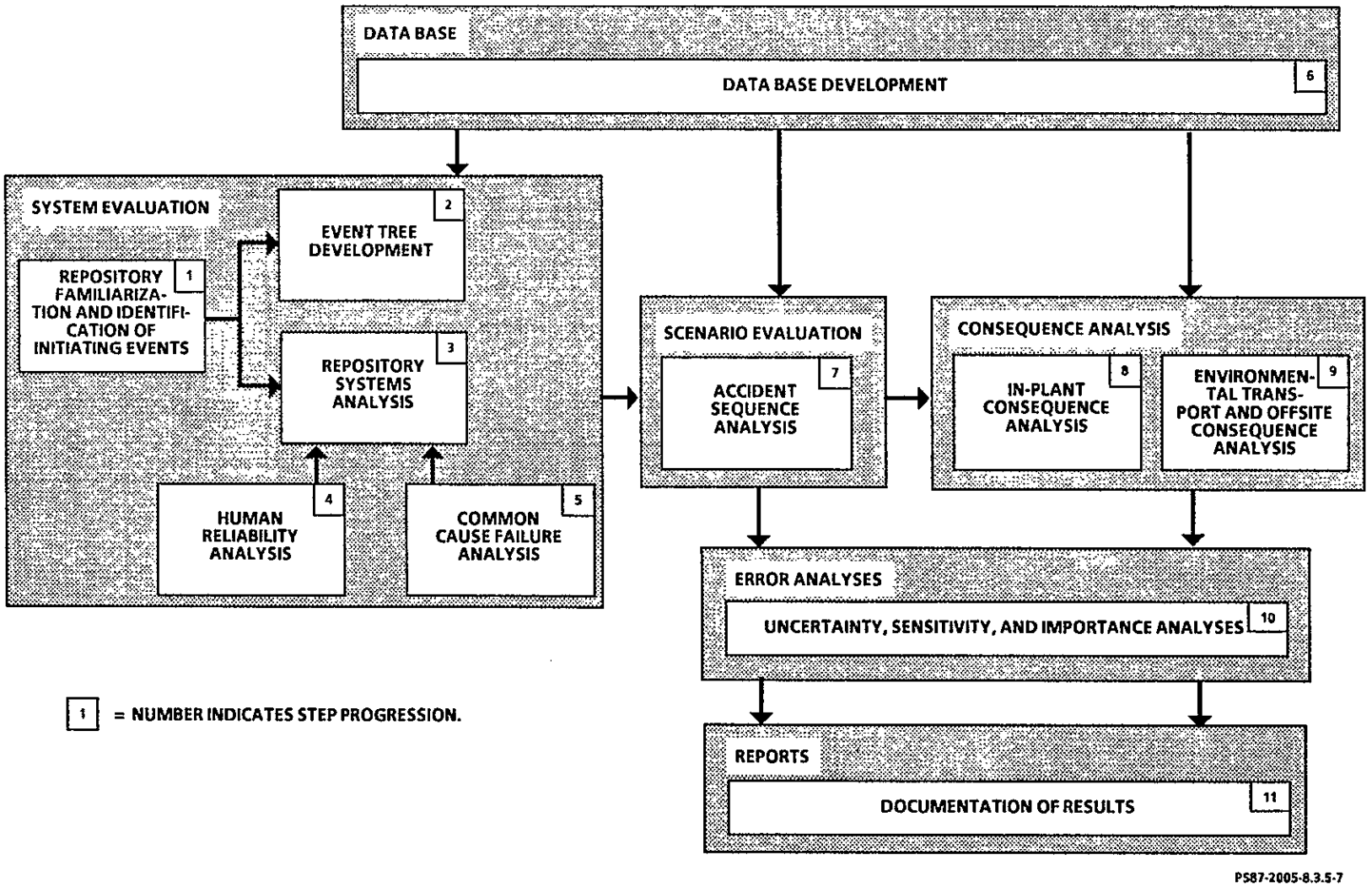

Figure 8.3.5-3. Analytical steps for assessing radiological risks from accidents.

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events will include external natural phenomena (e.g., earthquakes), external man-caused phenomena (e.g., an airplane crash), equipment failure (e.g., waste-hoist cage fall), and human errors (e.g., transporter crash). The Preclosure Risk Assessment Methodology (PRAM) program will identify a list of initiating events that are common to all repository sites and estimate their probability of occurrence. In addition, guidelines on identifying site-specific initiating events and the threshold probabilities for establishing the credible initiating events will be established.

8.3.5.1.3.2 Step 2--Event tree development

This step will identify the potential accident sequences that could occur following the initiating events. Accident sequences are commonly identified using event tree modeling techniques. An event tree model will be constructed for each credible initiating event (Step 1). The model will identify a set of accident sequences based on the response of the surface and subsurface systems, repository processes, and reactions of the operator to the initiating event. The potential accidents will be screened, usually through an iterative process based on their estimated frequency of occurrence (Step 7) and the consequences (Steps 8 and 9). From the iteration process, a set of dominant accident sequences will be determined. The dominant accident sequences can be used to complement the set of design basis accidents that may be required by regulatory authorities. Design basis accidents are the postulated accidents and resulting conditions for which the confinement structures, systems, and components must meet their functional goals. For the advanced conceptual design and license application design, the PRAM program will establish the methods and assumptions for event tree modeling and a common naming scheme for the top level repository systems and support systems.

8.3.5.1.3.3 Step 3--Repository systems analysis

This step will develop the reliability models for the repository systems and support systems necessary for the quantification of the potential accident sequences identified in Step 2. The information needed for these models is obtained from Steps 1, 4, 5, and 6 (see Fig. 8.3.5-3). These models are necessary for the quantification of the accident sequences (Step 7). The PRAM program will establish the appropriate reliability modeling techniques to be used by all repository projects. The level of analysis will depend on the level of design and on input from Steps 1, 4, 5, and 6. For each design phase, the process described in Figure 8.3.5-3 will be implemented, perhaps more than once during that design phase. During the earlier design phases, feedback of safety analysis results into the design process will be emphasized. During later phases, emphasis will be on use of safety analysis to verify compliance with regulations. Potential techniques include fault tree analysis, failure mode and effects analysis (FMEA), GO Methodology, and the Reliability Block Diagram. The PRAM program will probably recommend a combination of reliability techniques (e.g., fault tree analysis with FMEA). It should be noted that the designers perform FMEA as part of the design process. The FMEA provides valuable and structured input for Step 1.

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8.3.5.1.3.4 Step 4--Human reliability analysis

This step will identify the human errors to be included in the preclosure safety assessment, provide the probability estimates for these errors, and assist in the inclusion of human recovery actions to mitigate the consequences of accidents. The human reliability analysis has direct input to Step 3 and will provide insights to improve design and (or) to use certain types of procedures and operator training. The PRAM program will establish the appropriate human reliability analysis methods, computer codes, and assumptions for each design phase. Human reliability analysis data will be developed under Step 6. The level of human reliability analysis effort will depend on the level of design information.

8.3.5.1.3.5 Step 5--Common cause failure analysis

This step will identify the failures of multiple equipment items occurring from a single common cause (e.g., a loss of electric power that causes failure of several repository systems). The results of Step 5 will be used in Step 3. The level of detail of common cause failure analysis will depend on the level of design information. Areas of common cause failure analysis that need to be addressed include common cause accident initiating events (e.g., floods, fire, and loss of electric power), intersystem dependencies, and intercomponent dependencies. The PRAM program will establish the appropriate methods, computer codes, and assumptions to be used by the repository projects. Common cause failure analysis data will be developed as part of Step 6.

8.3.5.1.3.6 Step 6--Data base development

This step will develop the data bases for the analytical steps of the preclosure safety assessment. As shown in Figure 8.3.5-3, data are needed for Steps 3, 4, 5, 7, 8, and 9. The PRAM program will develop the data bases that are common to all repository sites. The unique site-specific data will be developed by the individual repository projects. As part of the development of site-specific data, the PRAM program will establish estimates on the following: (1) initiating event frequencies; (2) component failure, repair, test, and maintenance parameters; (3) human reliability; (4) common cause failures; and (5) data used in consequence analysis. The PRAM program will also establish the methods and assumptions for modifying the generic data for the specific sites and for treating data uncertainty. Much of the activity in this step occurs as part of Steps 1 through 5 and 7 through 9. The data base will be used to document and control the data used in the analysis.

8.3.5.1.3.7 Step 7--Accident sequence analysis

Step 7 will quantify the frequency of occurrence of the accident sequences identified in Step 2 by linking the system logic models (Step 3) and using the data developed in Step 6 for quantification. Each accident sequence will be transformed into a mathematical expression developed using Boolean algebra. Boolean algebra can be used to estimate the frequency of occurrence of the accident sequence and perform uncertainty and sensitivity analyses. An

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importance analysis (Step 10) will also be made to identify structures, systems, and components important to safety for supporting the formulation of the Q-list items. As mentioned in Step 2, the analysis of the results from Steps 2, 7, 8, and 9 will use an iterative process to identify dominant accident sequences that can be used to compliment the set of design basis accidents that may be developed in response to regulatory requirements. The PRAM program will establish the methods, computer codes, and assumptions to be used by the repository projects on (1) Boolean equation reduction, (2) the probability threshold for minimal cutsets, (3) the treatment of human recovery, and (4) the frequency threshold for identifying credible or dominant accident sequences. In addition, the PRAM program will establish the screening process for identifying and incorporating accident sequences, including low probability/high consequence sequences, into more general release categories to facilitate subsequent consequence analyses.

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8.3.5.1.3.8 Step 8--In-plant consequence analysis

This step is designed to determine the accident consequences within the repository site boundary, including the surface and underground facilities. These consequences include radiological health effects to essential workers.

In-plant consequence analysis will be performed for the selected design basis accidents and (or) the full set of dominant accident sequences. A consequence model representing the course of events, from accident initiator to personnel exposure, will be developed for the surface and underground facilities. Computer codes and analytical models will be used to describe the accident radionuclide release mechanisms, the resulting source term, radionuclide transport in the surface and underground facilities to the surface release points, and radiological health effects to essential workers. The PRAM program will develop the methods, computer codes, and assumptions to be used by the repository projects to ensure that consistency is maintained throughout the program.

8.3.5.1.3.9 Step 9--Environmental transport and offsite consequence analysis

This step will be used to determine the accident consequences outside the repository site boundary. These consequences include radiological health effects on the general public from radiological accidents.

The release categories will be refined based on the results from Steps 7 and 8 to minimize the offsite consequence analysis effort. The PRAM program will establish the methods, computer codes, and assumptions for air and water dispersion, pathway to man, dosimetry, and health effects modeling to be used by the repository projects to ensure program consistency. Many of these methods and models, however, may be highly site specific. The data will be developed in Step 6. The accident consequences may be classified into broad classes, ranging from negligible consequences (Class C-4) to potentially major public impact (Class C-1). These classes are further described in Table 8.3.5-1.

Table 8.3.5-1. Consequence definitions

Consequence	Class	Definition
Public	C-1	Event that has a potential for direct adverse impact to the public.
Major operational	C-2	Event during which a failure of a safety system would cause adverse public impact or would have a direct potential for serious adverse impact to operating personnel.
Minor operational	C-3	Event that would require another independently occurring event, in addition to a failure of a safety system, or failure of multiple safety systems to cause adverse public impact or has a direct potential for minor adverse impact to operating personnel.
Negligible	C-4	Event that has negligible or no human injury potential but could hinder repository construction, operation, or decommissioning.

8.3.5.1.3.10 Step 10--Uncertainty, sensitivity, and importance analyses

There are three objectives in this step. The first objective is to analyze the uncertainty in the results due to the uncertainty in the parameter and models. Uncertainties in the accident sequence likelihood estimates (Step 7), the releases to the environment (Step 8), and the risk to the public health and safety (Step 9) can be computed. The second objective, a sensitivity analysis that is often a useful adjunct to an uncertainty analysis, determines how much the output of an analysis changes with respect to variation in the input. The third objective is to identify and rank the important accident sequences, system failures, component failures, and human errors with regard to the accident sequence likelihood estimates. This is achieved by performing an importance analysis. The importance analysis will identify the important-to-safety structures, systems, and components and will assist in the formulation of the Q-list items for the advanced conceptual design and license application design. The PRAM program will develop overall methods for combining the uncertainties and sensitivities from all the analytical steps and will also establish the importance analysis methods that will be used to support the preparation of the Q-list items.

8.3.5.1.3.11 Step 11--Documentation of results

This step will document the safety assessment methods and results to support the various Office of Civilian Radioactive Waste Management activities. The PRAM program will develop or adopt annotated outlines for the documentation. A preclosure safety assessment report is planned to support the advanced conceptual design report, and the safety assessment results will be based on the advanced conceptual design information. A more detailed preclosure safety assessment report is planned to support the preparation of the safety analysis report, the environment report, and the environmental impact statement. This second report will be based on the license application design information.

The safety analysis report and environment report support license application, and the environmental impact statement supports site selection. The PRAM program will establish the role of the preclosure safety assessment report in relationship to the safety analysis report. Safety assessment results from the analytical approaches described in Sections 8.3.5.1.3 and 8.3.5.1.4 can be used to improve the preclosure repository safety. An important principle of safety is that it is better to prevent or reduce the frequency of occurrence of an accident than to mitigate its consequences. When appropriate, preventive safety measures will be incorporated into the repository design as it matures. Selection of preventive measures will be based on the results from Steps 7, 8, and 9, with additional safety insights from Step 10.

Safety assessment results can also be used to improve preclosure repository safety by identifying mitigative measures. Given accidents of various probabilities and consequences, which together constitute the incremental risk for significance of the event, it is possible to identify design and procedural measures that can reduce the risk. Those measures taken to lessen the consequences of potential accidents are termed "mitigating features." Recommendations of mitigative measures will be based on results from Steps 7, 8, and 9, with additional insights from Step 10.

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8.3.5.1.4 General analytical approach for assessing radiological risks from routine operations

The general analytical approach for assessing radiological risks from routine operations is illustrated in Figure 8.3.5-4 and is generally quite different from the approach used for assessing radiological risks from accidents. The risk from routine radiological exposures to the workers and the public can be determined from both actuarial and predictive models. Radiological accidents primarily use predictive models to assess risk. The analytical steps are briefly described below, and their results are applicable to risk categories RRP and RRW (see Section 8.3.5.1.1 for category descriptions). The PRAM program will develop the safety assessment methods described in the following steps. Some of the analytical steps and results of the accident risk approach may also be applicable for assessing the routine categories.

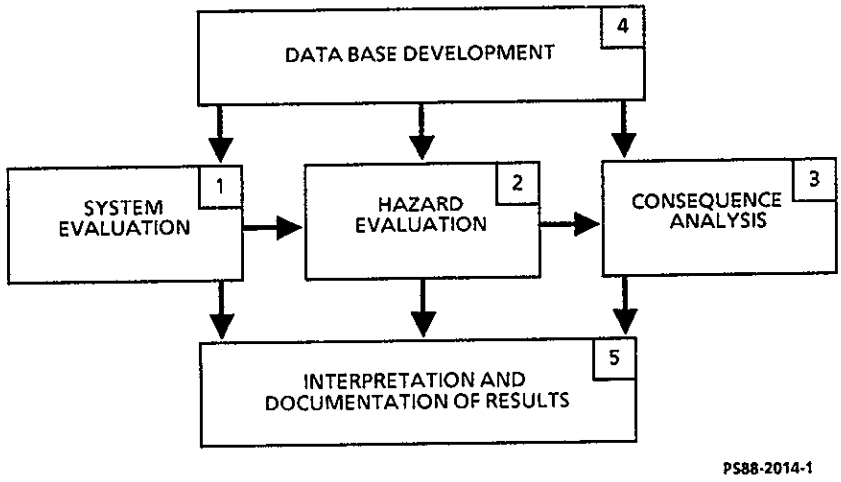

Figure 8.3.5-4. Analytical steps for assessing radiological risks during routine operations.

8.3.5.1.4.1 Step 1--Facility and site description (system evaluation)

This step is used to describe the physical configuration and processes of the repository site and facilities. It may require information similar to that identified in Section 8.3.5.1.3. If additional description is needed to characterize routine risks, it must be consistent with the description identified for the accident risk approach.

8.3.5.1.4.2 Step 2--Definition of sources and magnitude of potential hazards (hazard evaluation)

This step identifies the sources and the magnitude of the potential hazards. This step will require characterization of the radiation fields and airborne radionuclide concentrations in the surface and underground facilities to estimate the routine radiation doses to the workers. The sources and amounts of radioactive effluents released from the repository site will be characterized to estimate impacts to the surrounding population.

8.3.5.1.4.3 Step 3--Estimation of the consequences (consequence analysis)

The objective of this step is to estimate the number of people (i.e., workers and public) that are exposed to the hazard, analyze the pathways from the source to the people, and estimate the magnitude and potential health effects of the exposures. The exposures to the maximally exposed individuals and to the surrounding populations will be estimated, as required by the applicable regulations.

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The general approach used for estimating worker routine radiation doses is to estimate radiation levels in occupied areas; determine the personnel requirements and duration of activities in these areas; and then combine the dose rates, durations, and personnel estimates to generate the occupational dose estimates. Models to estimate the resulting health effects are then applied. Routine risks to the public are estimated by establishing effluent release rates for radioactive materials; determining the efficiency of the building ventilation/filtration systems; applying a dispersion model, using site-specific population and weather distributions; and estimating the resulting exposures to the surrounding population. Models to estimate the radiological health effects are then applied. The PRAM program will establish the appropriate methods, computer codes, and assumptions to be used by the repository projects to perform these analyses.

8.3.5.1.4.4 Step 4--Data base development

This step will develop the data needed for calculating the routine or normal risks from radiological incidents. Examples of key data needs are information on source terms, ventilation system performance, plateout of materials, and health effect conversion factors.

8.3.5.1.4.5 Step 5--Interpretation and documentation of results

The objective of this step is to interpret and document the safety assessment results in support of all the end uses. Uncertainty and sensitivity analyses may be used to interpret the results. The results will be documented along with the results of assessing radiological risk from accidents. (See Step 11 in Section 8.3.5.1.3.)

8.3.5.1.5 Schedule and plans for preclosure safety assessment

Preclosure safety assessments involving the activities discussed previously are performed in an iterative manner throughout the design phases of the project. The quantity and detail of information used during these analyses will improve with time. For example, the safety assessment performed in support of the advanced conceptual design will be more detailed than the one performed for the conceptual design. The final preclosure safety assessment, performed with the design and site information available at the completion of site characterization, will provide input to both the safety analysis report and the environmental report. These two documents will constitute the license application, as specified and described in 10 CFR 60.21 (NRC, 1987a). Input will also be provided to the environmental impact statement, which supports site selection.

The advanced conceptual design is planned to be initiated by February 1989 (FY 1989). Preclosure safety assessments will be performed to

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support this design activity using the PRAM program. Prior to initiation of advanced conceptual design, the following tasks will be completed:

- Definition of accident initiators for input at the start of the advanced conceptual design.
- Definition of design basis accidents for incorporation into the advanced conceptual design statement of work.
- Development of safety analyses methods in conjunction with the PRAM program for input at the start of the advanced conceptual design. In particular, repository transport modeling, entity-relationship modeling, and accident source-term modeling will be developed.

After the initiation of advanced conceptual design, tasks will be initiated as follows:

- Preliminary safety assessment based primarily on conceptual design and statement of work data for input at 30% advanced conceptual design.
- Design recommendations for preventive and mitigative features based on preliminary safety assessments for input at 30% advanced conceptual design.
- Repository system description updates during the 30% to 60% advanced conceptual design.
- An advanced conceptual design safety assessment during the 30% to 60% advanced conceptual design to be completed at 100% advanced conceptual design.
- An advanced conceptual design Q-list to be completed at 100% advanced conceptual design.

A schedule for preclosure safety activities is shown in Figure 8.3.5-5.

8.3.5.2 Strategy for postclosure performance assessment

This section describes the plans for assessing the long-term behavior of the repository subsystems (engineered barriers, repository seals, and site) and integrating such assessments into a unified evaluation of overall geologic repository system performance.

Postclosure performance assessment is a major component of the issue resolution strategy. The activities discussed in this section are directed primarily toward the resolution of Key Issue 1, postclosure performance (see Section 8.2.2.1.1). A brief discussion of performance and design issues as they relate to postclosure performance assessment activities is provided in

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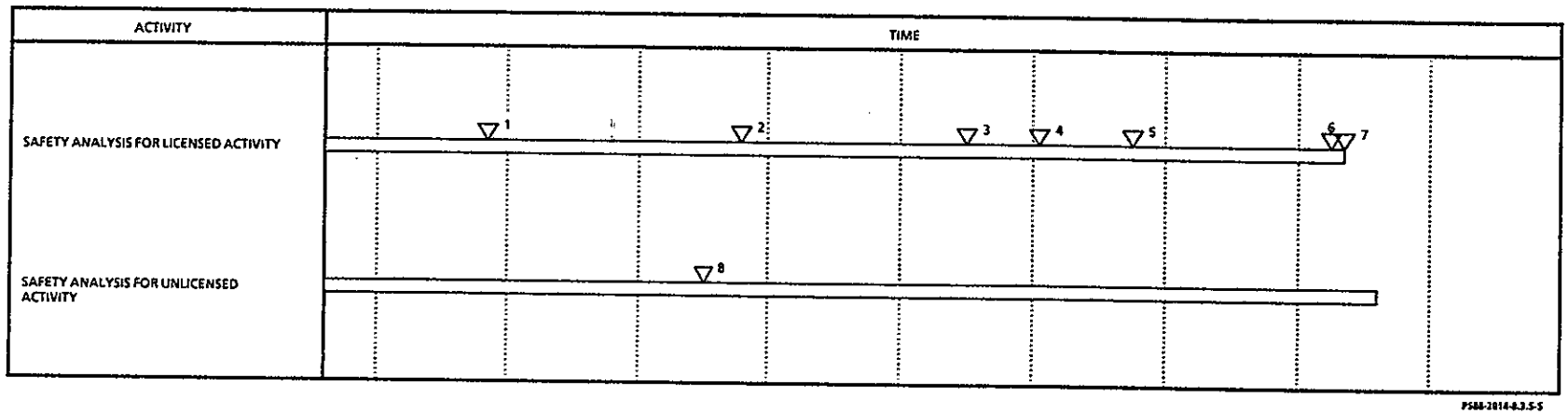


1 ISSUE BASALT REPOSITORY PRELIMINARY Q-LIST.
2 COMPLETE REPOSITORY 30% ACD SAFETY REVIEW.
3 ACD SAFETY ASSESSMENT COMPLETE.
4 REVISE Q-LIST FOR LAD.
5 COMPLETE REPOSITORY 30% LAD SAFETY REVIEW.
6 RESOLUION OF ISSUES 2.1, 2.2, 2.3, AND 2.5.
7 LAD SAFETY ANALYSIS COMPLETE.
8 ISSUE EXPLORATORY SHAFT FACILITY SAFETY ANALYSIS REPORT.

ACD = ADVANCED CONCEPTUAL DESIGN
LAD = LICENSE APPLICATION DESIGN

Figure 8.3.5-5. Preclosure safety analysis schedule.

CONSULTATION DRAFT

the following sections. The results from analyses of subsystem and system performance will be used to assess compliance with performance requirements and to guide data collection and site characterization work (see Sections 8.3.1 through 8.3.4).

Because the assessments must address performance of the repository system for thousands of years into the future, the analyses are expected to rely heavily on modeling. Performance assessments involve the development and application of conceptual and mathematical models of the system. In most cases, computer codes are used to implement these mathematical models. Other methods, such as full-scale laboratory and field experiments, are precluded by the requirement to demonstrate performance for 10,000 yr and beyond. However, data from short-term laboratory, natural analog, and field experiments will be used to help validate the models.

The major activities in postclosure performance assessments include (1) defining conceptual models and scenarios in terms appropriate for performance assessment, (2) developing numerical models and computer codes that mathematically simulate system and subsystem performance, (3) conducting sensitivity and uncertainty analyses, (4) identifying and interpreting subsystem performance objectives, (5) predicting the performance of the repository subsystems and system, and (6) providing information to other project groups to promote informed decisions. The coordination of these steps (Fig. 8.3.5-6) can direct project activities toward a cost-effective determination of site suitability. The process is sufficiently flexible to accommodate alternative engineered barriers and repository seals subsystem designs, alternative subsystem conceptual models, or changes in information requirements. Figure 8.3.5-7 shows the schedule for postclosure performance assessment.

The postclosure performance requirements are found in the following Federal regulations:

- 10 CFR 60 (NRC, 1987a).
- 40 CFR 191 (EPA, 1986).
- 10 CFR 960 (DOE, 1987a).

All performance objectives are based on these Federal regulations. The regulations place performance requirements on the following:

- Cumulative releases of radionuclides to the accessible environment during the 10,000 yr after repository closure.

- Individual protection requirements for any member of the public in the accessible environment, in terms of maximum allowable radiation dose and minimum protection time.

- Groundwater protection requirements, in terms of maximum allowable radionuclide concentrations, minimum protection time, and dose limits.

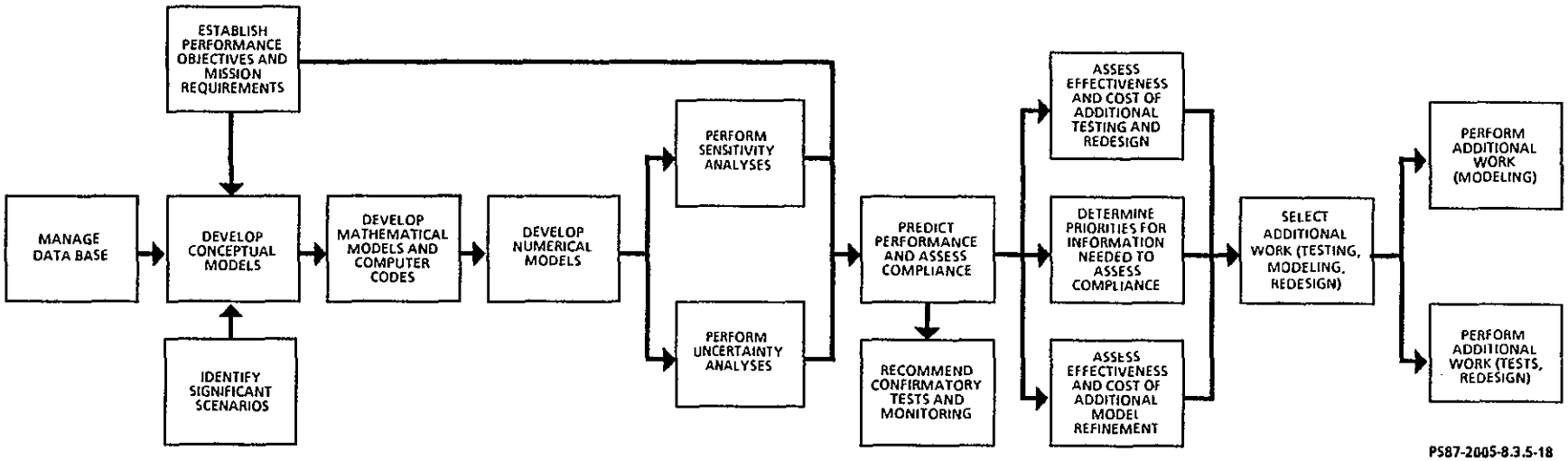
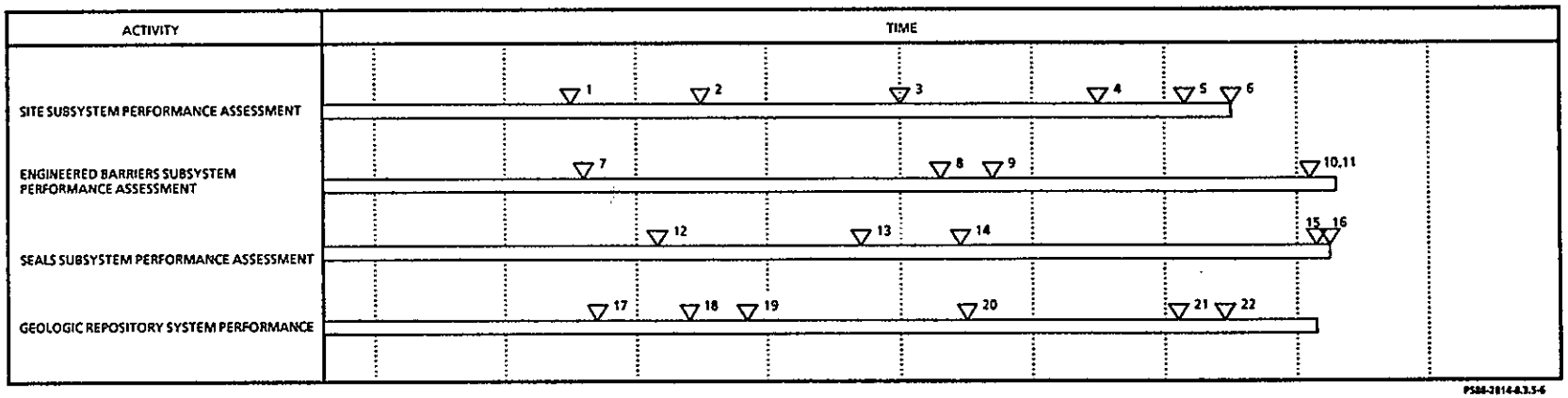


Figure 8.3.5-6. Postclosure performance assessment activities.

CONSULTATION DRAFT



1 LARGE-SCALE HYDRAULIC STRESS PRE-TEST ANALYSIS.
2 GROUNDWATER FLOW CONCEPTUAL MODEL DEFINITION FOR ACD.
3 GROUNDWATER TRAVEL TIME ANALYSIS IN SUPPORT OF ACD PPA.
4 GROUNDWATER FLOW CONCEPTUAL MODEL DEFINITION FOR LAD.
5 GROUNDWATER TRAVEL TIME ANALYSIS IN SUPPORT OF LAD PPA.
6 RESOLUTION OF ISSUE 1.6, GROUNDWATER TRAVEL TIME.
7 COMPLETE SENSITIVITY ANALYSIS IN SUPPORT OF LAD.
8 COMPLETE ACD PERFORMANCE ASSESSMENT.
9 COMPLETE SENSITIVITY ANALYSIS IN SUPPORT OF LAD.
10 COMPLETE LADE PERFORMANCE ASSESSMENT.
11 DOCUMENT RESOLUTION OF ISSUE 1.4, WASTE PACKAGE CONTAINMENT, AND ISSUE 1.5, RADIONUCLIDE RELEASE RATES.
12 COMPLETE SEALS SENSITIVITY ANALYSES FOR ACD.
13 COMPLETE SENSTIVITY ANALYSIS FOR LAD ALLOCATION.
14 COMPLETE PERFORMANCE ASSESSMENT OF FINAL ACD.
15 COMPLETE PERFORMANCE ASSESSMENT FOR LAD.
16 DOCUMENT RESOLUTION OF ISSUE 1.12, SHAFT AND BOREHOLE SEALS.
17 DEFINE AND DEVELOP PERFORMANCE ASSESSMENT DATA BASE.
18 CONDUCT SCENARIO SENSITIVITY ANALYSIS.
19 CONDUCT FINAL BARRIER SENSITIVITY ANALYSIS.
20 CONDUCT POSTCLOSURE PERFORMANCE ASSESSMENT FOR ACD.
21 CONDUCT ANALYSIS FOR DRAFT ENVIRONMENTAL IMPACT STATEMENT.
22 CONDUCT PPA FOR LAD.

ACD = ADVANCED CONCEPTUAL DESIGN
LAD = LICENSE APPLICATION DESIGN
PPA = POSTCLOSURE PERFORMANCE ASSESSMENT

Figure 8.3.5-7. Postclosure performance assessment schedule.

CONSULTATION DRAFT

- Radionuclide rate of release from the engineered barriers subsystem for individual radionuclides.
- Radionuclide containment by the waste packages.
- Preemplacement groundwater travel time to the accessible environment.

The performance measures currently are the focus for assessing postclosure compliance with the regulations. The regulations that define the postclosure performance objectives in terms of performance measures are summarized in Table 8.3.5-2. Strategies for resolution of issues derived from these regulations are discussed in Section 8.2. These strategies define the information needed to perform the performance assessments discussed in this section.

The following activities are important to postclosure performance assessment. These activities are the focus of subsequent discussion.

- Defining scenarios. The proposed method used for identifying and describing site-specific conditions, processes, and events that compose credible scenarios is provided in Section 8.3.5.2.4.1. The method identifies scenarios with potentially significant consequences and evaluates their occurrence probabilities.
- Developing conceptual models. Conceptual models qualitatively describe subsystems in terms of both the current understanding of their physical description and the processes governing their behavior. Such models will be based on engineering design concepts and the accumulated body of site-specific knowledge. They describe the subsystems in terms appropriate for subsequent development of the numerical models simulating subsystem performance. Plans for selecting preferred conceptual models and for evaluating the probability that each conceptual model is correct for each scenario selected for purposes of analysis are discussed in Sections 8.3.5.2.1.1, 8.3.5.2.2.1, 8.3.5.2.3.1, and 8.3.5.2.4.2.
- Developing mathematical models and computer codes. The processes, events, and (or) conditions important to each subsystem are expressed in terms of mathematical equations. The principles of conservation of mass, momentum, and energy form the basis for formulating the governing equations for many of the mathematical models. Depending on the complexity of the mathematical model, a numerical algorithm (computer code) may be required in order to provide a solution. Both deterministic and probabilistic or stochastic computer codes will be used in performance assessment. Development will include activities to verify and benchmark codes.

Table 8.3.5-2. Postclosure performance objectives for a high-level nuclear waste geologic repository

Performance issue	Regulation	Topic	Application	Reference	Performance objective
1.1	40 CFR 191.13	Radionuclide isolation	Overall repository system	EPA (1986)	Cumulative radionuclide release to the accessible environment during the first 10,000 yr after repository closure shall not exceed limits specified.
1.2	40 CFR 191.15	Individual protection	Overall repository system	EPA (1986)	Undisturbed performance of the repository shall not cause the annual dose equivalent to the public in the accessible environment to exceed specified limits for 1,000 yr after waste disposal.
1.3	40 CFR 191.16	Groundwater protection	Overall repository system	EPA (1986)	Undisturbed performance of the repository shall not cause contamination of special sources of groundwater exceeding specified concentration and dose limits for 1,000 yr after disposal.
1.4	10 CFR 60.113	Radionuclide containment	Waste package	NRC (1987a)	Containment of radionuclides in the waste packages shall be substantially complete for a period between 300 and 1,000 yr after permanent closure of the geologic repository.
1.5	10 CFR 60.113	Radionuclide release rates	Engineered barriers subsystem	NRC (1987a)	Annual releases from the engineered barriers subsystem shall be gradual and shall not exceed 10^{-5}/yr of the inventory after the containment period (does not apply to radionuclides that contribute <0.1% of the total annual release limit).
1.6	10 CFR 60.113	Groundwater travel time	Site subsystem	NRC (1987a)	Minimum pre-emplacement groundwater travel time from the disturbed zone to the accessible environment shall be >1,000 yr.
1.7	10 CFR 60.137	Performance confirmation	Overall repository system and subsystems	NRC (1987a)	Confirm that predicted performance will be achieved.
1.8	10 CFR 60.122	Favorable and potentially adverse conditions	Site subsystem	NRC (1987a)	Assess presence and significance of favorable and potentially adverse conditions specified in regulation.
1.9	10 CFR 960.4 and 960.3-1-5	Higher level findings and site comparisons	Overall repository system	DOE (1987a)	Reach higher level findings on qualifying and disqualifying conditions and define performance in 100,000 yr for site comparisons.

NOTE: (1) 10 CFR 60 (NRC, 1987a) and 40 CFR 191 (EPA, 1986) regulations present numerical system and subsystem performance requirements. Regulations of 10 CFR 60 provide that the subsystem requirements may be modified, subject to approval by the NRC.

(2) In addition to the above performance objectives, reasonable assurance of compliance must be demonstrated in terms quantified by 40 CFR 191.14.

(3) CFR = Code of Federal Regulations.
DOE = U.S. Department of Energy.
EPA = U.S. Environmental Protection Agency.
NRC = U.S. Nuclear Regulatory Commission.

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- Developing numerical models. Numerical models (i.e., the computer code that implements the conceptual and mathematical models plus the supporting site-specific data) will be used to assess the performance of the repository system and subsystems. This step requires incorporating site-specific data into the computer codes. A systematic method of quantitatively evaluating and translating data into a meaningful set of model parameters is required. Validation, as described in Section 8.3.5.3.4, is an essential facet of numerical model development.

- Assessing subsystem and system performance. This activity consists of the periodic analyses performed to assess the performance of both the subsystems and the system. An analysis of the system, as reflected in the conceptual design and existing data base, will be performed. The analysis will be upgraded to include the advanced conceptual design and the upgraded data base. The use of sensitivity and uncertainty analyses is included as part of this activity. In particular, the performance of the subsystems and the system will be evaluated with respect to the performance objectives defined by the performance issues (see Section 8.2.2).

- Planning model validation and confirmatory tests and monitoring. Detailed plans for confirmatory tests and monitoring will be defined in the future. From a postclosure performance assessment perspective, confirmation augments model validation activities.

The status of the BWIP conceptual and numerical models for each of the subsystems and systems will be discussed in the following sections. Plans for analyses in support of project milestones will also be discussed.

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8.3.5.2.1 Plans for assessing engineered barriers subsystem performance

The engineered barriers subsystem is defined as the waste form, waste container, packing material enclosing the waste container, and backfill in the emplacement rooms. The shaft backfill and seals, and seals for test boreholes drilled from the surface, are not included. Portions of the backfill placed in the access and ventilation drifts may be designed to restrict groundwater flow to the shafts. These portions are considered to be part of the repository seals subsystem for purposes of postclosure performance assessment. This categorization differs from that given for the engineered barriers subsystem in 10 CFR 60.2 (NRC, 1987a); the NRC defines the engineered barriers subsystem as the waste package and all of the underground facility. The difference in subsystems was adopted to allow consolidation of physically connected, conceptually similar seals into one subsystem rather than grouping horizontal seals into one subsystem and vertical seals into another.

Commercial nuclear fuel typically consists of compressed and sintered cylindrical pellets originally composed of enriched uranium oxide. In a repository, the fuel and its Zircaloy cladding will be contained in a thick-walled, metal container. This container will isolate the waste from groundwater during the time when radiation and thermal output from the waste are relatively high. Planned performance assessment studies will consider the effects of adding other waste forms and defense-related nuclear wastes to the repository inventory.

The packing material surrounding the waste containers will help to restrict radionuclide release rates to the host rock by providing favorable transport properties.

The engineered barriers subsystem must comply with the performance objectives specified for that subsystem and its components in Table 8.3.5-2. In addition, the engineered barriers subsystem must contribute to the system performance objectives (see Table 8.3.5-2). The proposed approach (logic) for assessing the postclosure performance of the engineered barriers subsystem is shown in Figure 8.3.5-8. This logic incorporates activities that are discussed in the following paragraphs and elsewhere in Chapter 8. The activities shown in the middle of the logic (i.e., develop conceptual models, define scenarios, develop mathematical and numerical models, and assess subsystem performance) are discussed in the paragraphs that follow. The activities or elements identified at the top and bottom of the logic are discussed in Sections 8.3.2 and 8.3.4.

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8.3.5.2.1.1 Conceptual model(s) for engineered barriers subsystem

Conceptual models in performance assessment are defined as generally qualitative descriptions of the physical characteristics (geometry) of the subsystem and the applicable governing physical processes. (Quantitative characteristics are addressed in Section 8.3.5.2.1.2.) The conceptual models must represent all of the interrelated phenomena involved in engineered barriers subsystem performance. These phenomena are geochemistry, two-phase groundwater flow (i.e., repository resaturation), thermal transport, radiation shielding, radiolysis, corrosion, radionuclide release and transport, and structural behavior. Preliminary conceptual models have been developed based upon the results of work summarized in Chapter 7. Technical concerns such as advective radionuclide transport that must be addressed to refine the current conceptual models are discussed in issue resolution strategies (Section 8.2.2). The process of conceptual model development is illustrated by the example of the radionuclide release and transport model in the following paragraphs.

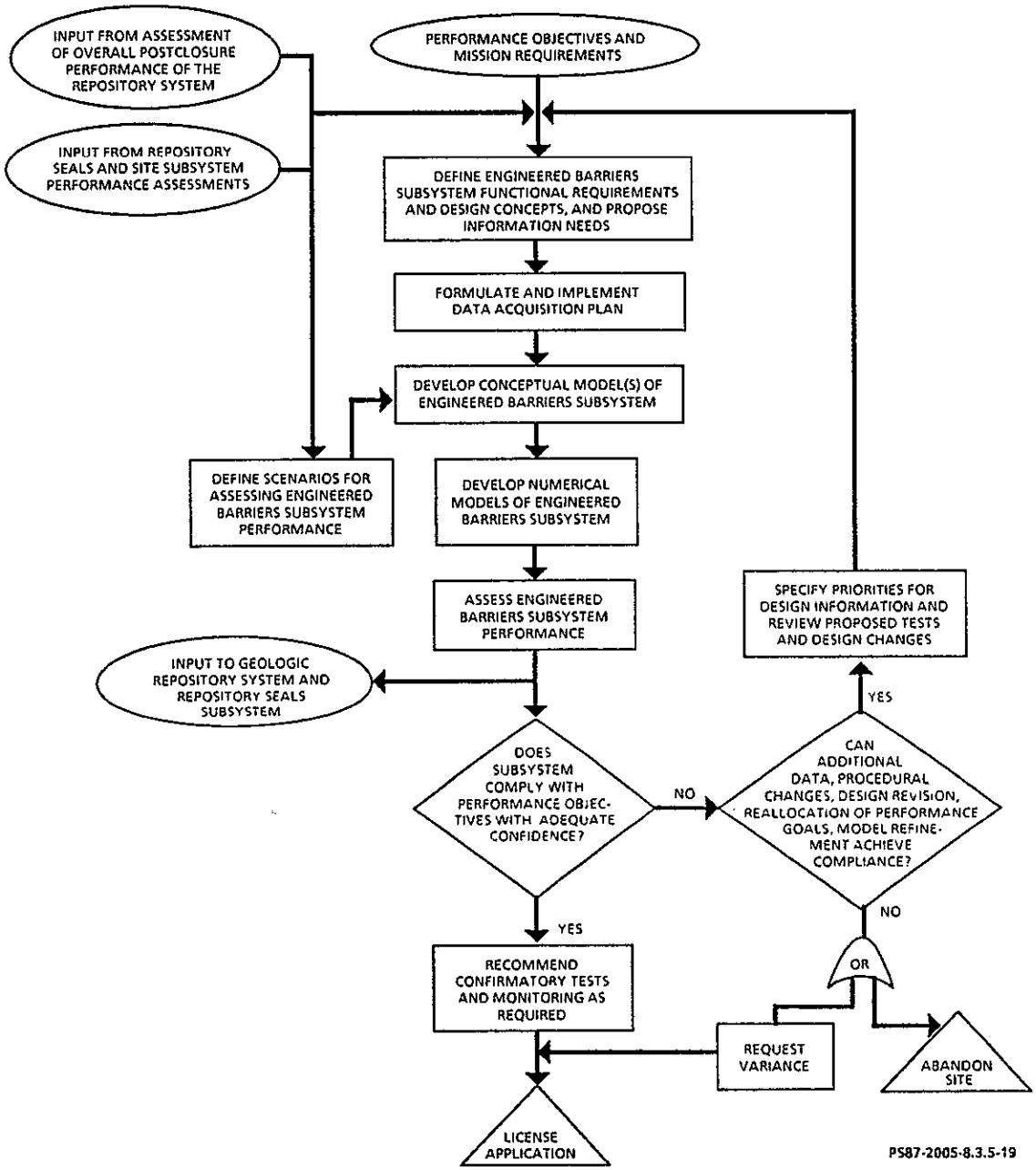

Figure 8.3.5-8. Engineered barriers subsystem performance assessment.

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Conceptual models of radionuclide transport in the engineered barriers subsystem account for the processes of radionuclide migration from the engineered barriers subsystem to either the site or the repository seals subsystem. Steps taken in developing such conceptual models for the engineered barriers subsystem are as follows:

- Identify mechanisms and processes affecting radionuclide releases for both nominal and disruptive conditions.
- Delineate paths of radionuclide migration.
- Identify processes, boundary conditions, and subsystem characteristics that can be controlled by engineering design or material selections to limit or inhibit releases of radionuclides.
- Identify the dimensions of the model, the configuration of the coordinates, and the geometric shapes of the various components of the system that are compatible with the processes identified by the first three steps.

Based on results from these steps, appropriate and defensible simplifying assumptions are made to eliminate those processes and geometric aspects that may be simplified or neglected without decreasing the conservatism of the analysis.

Alternative conceptual models based on reasonable alternative interpretations of available data will be considered. Further discussion of alternative models is provided in Section 8.3.4.5. Where possible, reasonable assurance will be provided by corroborating predicted performance independently. Such corroboration may include use of mathematical models developed by a different approach, extrapolation based on information from short-term laboratory tests, and comparison with analogous field and laboratory data where appropriate.

In order to establish the performance of the waste package in the context of the repository, radionuclide release must be modeled as two components: (1) the breach of the container and (2) the resulting migration of radionuclides. Uncertainty from factors such as varying thermal loading and manufacturing tolerance requires that the time of failure for a "typical" repository container be modeled as a probability density function. Conceptually, the repository will be modeled as a group of independent waste packages, each of which fails in accordance with this probability function. Generation of the container lifetime distribution is discussed in Section 8.3.4.5. Part of the continual development of the repository release model will be the evaluation of container failure distributions and failure mechanisms for individual containers.

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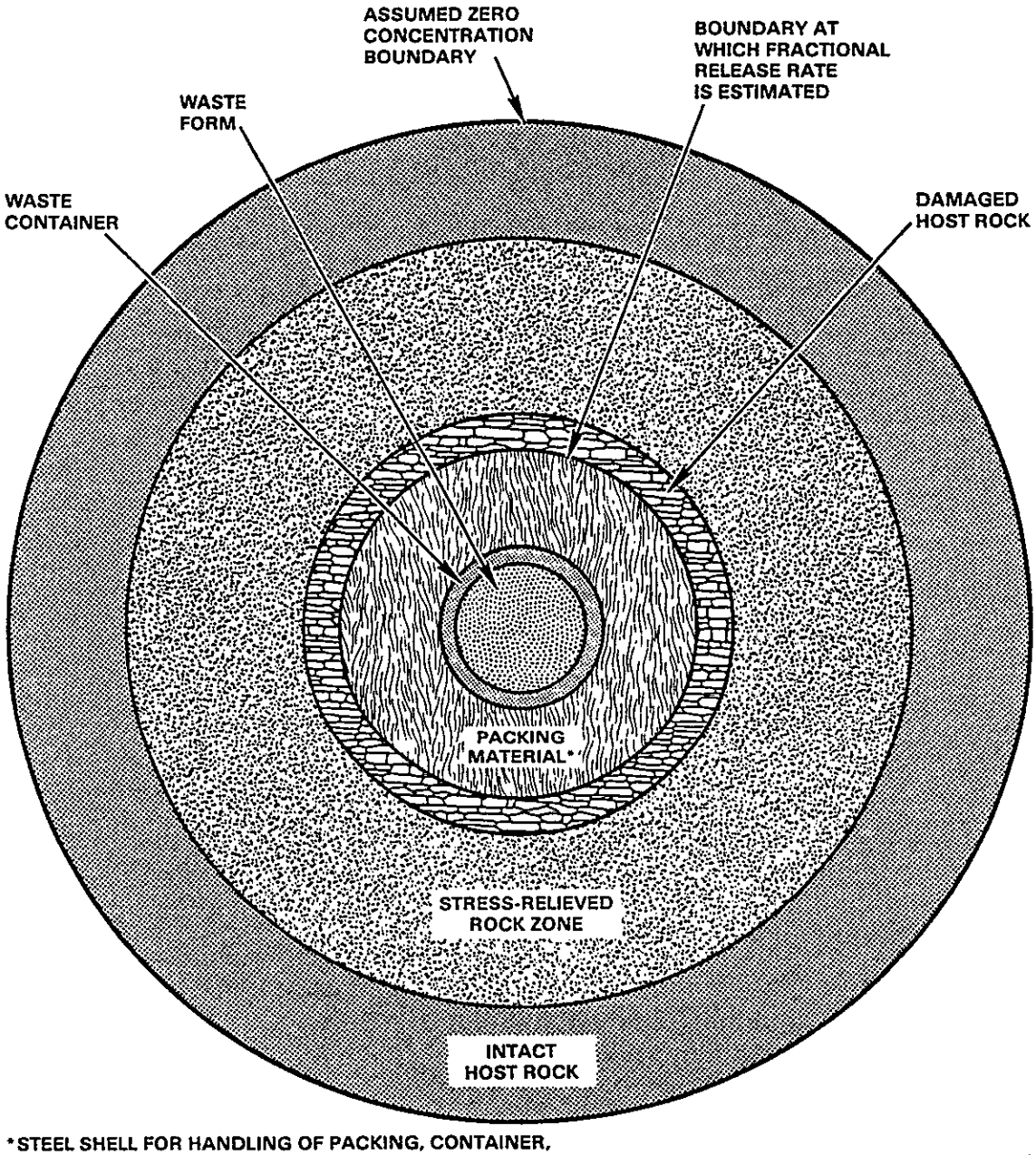
The present conceptual model for the radionuclide source at the waste form surface is a fixed concentration boundary until the radionuclide inventory is depleted. More realistic models may include (1) congruent release of radionuclides by dissolution of the uranium dioxide matrix; (2) progressive loss of radionuclide containment from individual containers in contrast to total, instantaneous exposure of the waste form on container failure; and (3) containment properties of the spent fuel cladding.

Diffusion is seen as the dominant process in the current conceptual model for radionuclide transport. Previous studies using simple, one-dimensional geometry (Baca et al., 1984; Relyea and Wood, 1984; Oliver, 1985) have indicated that the advective component of transport is negligible on the waste package scale. This assumption will be evaluated by numerically modeling advection that results from natural hydraulic gradients and convection that is buoyancy driven by radiogenic heat for any geometry assumed in the conceptual model. If groundwater circulation near the waste package is determined to be significant, it will be incorporated into the radionuclide transport models.

Released radionuclides encounter four material types in the vicinity of the engineered barriers subsystem: (1) the container packing material (a 3 to 1 mixture of crushed basalt and bentonite clay), (2) the rock around the waste package borehole damaged by excavation and subject to stress release expansion, (3) either crushed basalt or packing material within the emplacement room, (4) the intact host rock, and (5) container corrosion products. Only the properties of the intact host rock are not subject to some degree of engineering control. Radionuclide movement will consist of two flow path components: either perpendicular to the axis of the container and directly into the host rock (Fig. 8.3.5-9) or parallel to the axis, within the annulus of damaged rock and borehole packing, toward the emplacement room (Fig. 8.3.5-10). The model geometry (see Fig. 8.3.5-9 and 8.3.5-10) will be selected based on the significance attributed to each component and the location of the boundary where release limits are applicable (NRC, 1987a).

The following mechanisms and parameters important to radionuclide releases from the engineered barriers subsystem will be incorporated in conceptual model development as required to implement specific strategies described in Sections 8.2.2.1.1, 8.2.2.1.4, and 8.2.2.1.5:

- Solubilities of radionuclides.
- Inventories and spatial distribution of radionuclides.
- Effective diffusion coefficients of the packing material, emplacement room backfill, damaged rock, and host rock mass.
- Hydraulic conductivities, gradients, and dispersivities within the packing material, emplacement room backfill, and surrounding rock zones (to assess advective transport).



*STEEL SHELL FOR HANDLING OF PACKING, CONTAINER, AND WASTE FORM ASSEMBLY NOT SHOWN

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Figure 8.3.5-9. Subsystem configuration for computing radial release from the engineered barriers subsystem.

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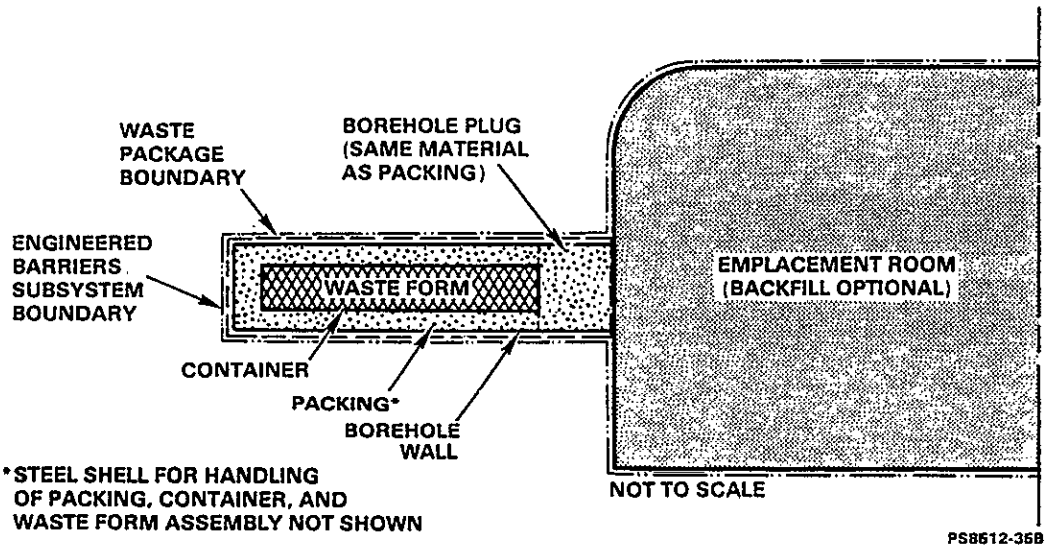

Figure 8.3.5-10. The engineered barriers subsystem.

- Radionuclide distribution coefficients in the packing material, emplacement room backfill, and host rock.
- Thermal, fluid, geochemical, and radiation environmental conditions.
- Porosity and density of packing material, emplacement room backfill, and host rock.
- Container lifetime distribution.
- Rate of waste-form matrix dissolution.
- Extent of waste container breaching.
- Containment properties of the spent fuel cladding.
- Temperature distribution in the waste container, packing material, and host rock.

Including each mechanism and parameter in mathematical models will allow a quantitative evaluation of the relative sensitivity of overall waste package performance to these parameters, thus guiding further conceptual model development. Sensitivity analyses will comprise the bulk of initial model evaluation in order to efficiently guide further testing and material characterization functions.

Analyses will consider the effects of temperature distribution in the vicinity of the waste package on temperature-dependent parameters (e.g., solubility, container corrosion, effective diffusion coefficient). At this time the importance of coupling has not been quantitatively established. Evaluating the sensitivity of each release-limiting component of the engineered barriers to temperature variations will be done during conceptual model development, and process coupling will be incorporated as appropriate.

8.3.5.2.1.2 Developing mathematical and numerical models of the engineered barriers subsystem

Stochastic mathematical modeling will be the preferred method of assessing compliance with the performance objectives of the engineered barriers subsystem. Stochastic modeling will be supplemented by deterministic modeling where appropriate. Deterministic models will be used to analyze phenomena that have a secondary effect on performance (e.g., radiolytic exacerbation of container corrosion). Deterministic models will be used in sensitivity studies in which it is important to identify the response of performance measures to specific variations in parameters.

Mathematical models of the engineered barriers subsystem are based on the governing processes of the subsystem conceptual model(s). These processes must be simulated in terms of parametric equations based on accepted scientific principles. The majority of the parametric equations will express a causal relationship (i.e., will relate a cause to its effect). The most

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common relationships of this type are those that stem from applying the principles of conservation of mass, momentum, and energy. In some cases, phenomenologically and (or) empirically based relationships may be used. Examples of relationships based on observed phenomena are both Darcy's and Fick's laws. These laws are used to describe, respectively, the flow of water and transport of mass in porous media. An illustration of an empirically based relationship is the use of an experimentally derived corrosion rate versus temperature relationship for steel waste containers (DOE, 1986a).

Equations that simulate processes important to assessing engineered barriers subsystem performance are expressed in terms of parameters characterizing those processes. The values of these parameters are deduced from site-specific field and laboratory data, published non-site-specific information, and expert opinion. Because of both the imperfect understanding of all of the processes and the assumptions involved in representing them with equations having a finite number of parameters, residual uncertainty exists from each step of the modeling process. The components of this residual, cumulative uncertainty will be identified and quantified as fully as possible. Such quantification will normally be in terms of multivariate probability distributions. Lacking that, quantification will be in terms of the expected values and variances of the uncertain quantities.

Not all uncertainties can be objectively quantified by statistical methods. Some uncertainties can be evaluated only subjectively (e.g., through peer review and expert judgment). For some parameters, formal elicitation of expert opinion by probability encoding will be used to quantify subjective estimates of probability (Runchal et al., 1984a, 1984b).

Stochastic mathematical models will be the principal means of analyzing engineered barriers subsystem performance. Uncertainties in the input data will be explicitly considered by these models. Several computer codes based on stochastic mathematical models have been developed and are presently in use for calculation of waste package performance. These analyses include the use of the PCM.STAT, the CHAINT-MC, and the REPREL computer codes. (A description of these computer codes is provided in Sections 8.3.5.4 and 8.3.5.5.)

The PCM.STAT computer code (Section 8.3.5.5.2.2) is used to calculate the corrosion rate, which in turn determines the container lifetime. A discussion on using the PCM.STAT code to evaluate the three waste package site characterization plan conceptual designs is in Section 7.4.6.3.5.3. The PCM.STAT code requires temperature input from thermal transport calculations and a time at which the packing becomes saturated with water. Thermal transport will be computed by a code such as TSAP or SINDA. Saturation will be computed by the GEOTHER code. A structural failure criterion will be obtained by analysis with ABAQUS. Future refinements in container corrosion modeling will be supported by geochemical analysis using EQ3/6, radiolysis analysis using MAKSIMA/CHEMIST or RADIOL, and radiation dose calculations by QADMOD-G, ONEDANT/TWODANT, or MORSE-SGC/S. The plan for performing these interrelated studies is described in Section 8.3.4.5. Criticality calculations will be accomplished with ONEDANT/TWODANT, KENO, or MORSE-SGC/S.

In future studies, if plans to develop a transport-limited corrosion model are successful (e.g., Walton and Sagar (1986a, 1986b)), this model (PACLIFE, Section 8.3.5.5.2) will be used to supplant or supplement PCM.STAT. The model will be used to estimate corrosion limits based on transport phenomens.

The CHAINT-MC code is used to calculate radionuclide transport from a single failed container. A discussion on using the CHAINT-MC code to evaluate the transport of radionuclides from the waste package for the site characterization plan conceptual design is in Section 7.4.6.3.5.4. The REPREL code is used to simulate the release and transport of radionuclides from the engineered barriers subsystem. This is accomplished by statistically combining the results from the CHAINT-MC and PCM.STAT analyses. Additional discussion on the use of the REPREL code is provided in Section 7.4.6.3.5.4.2.

In effect, the CHAINT-MC code is used to simulate the time-dependent transport of radionuclide from a single waste container assuming failure at time zero (t=0). The PCM.STAT code is used to calculate a probability density function of container lifetime for all waste containers in the repository. Using the principle of superposition, the results from these two analyses are combined. This approach has recently been documented by Sagar et al. (1986).

Section 7.4.6.3.5.3.1 provides a discussion of the assumptions and data base used to evaluate the container lifetime analysis for the waste package site characterization plan conceptual design. A discussion of the assumptions and data base used to evaluate radionuclide release and transport from the waste package site characterization plan conceptual design is provided in Sections 7.4.6.3.5.4.2.1 and 7.4.6.3.5.4.2.2. Discussions of plans for verification, benchmarking, and validation of computer codes and models are provided in Sections 8.3.4.5 and 8.3.5.4.

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8.3.5.2.1.3 Schedule and plans for assessing engineered barriers subsystem performance

The scope of planned work for conducting engineered barriers subsystem performance assessments includes model and code development, documentation and testing of computer codes and models, control of data used in support of analyses, application of models, interpretation of results, and the use of interpreted results to guide design and data collection activities. The scope of planned work will be discussed in terms of the performance assessment activities shown in Figure 8.3.5-8. Recommendations for confirmation testing will be made based on results of performance assessments. Activities for assessing postclosure performance of the repository seals subsystem are shown in Figure 8.3.5-11.

8.3.5.2.1.3.1 Conceptual model development

Most of the mathematical models and computer codes are considered to be well advanced for modeling the processes that determine waste package performance. The development or refinement of the conceptual models representing the waste package and repository geometry is ongoing. This

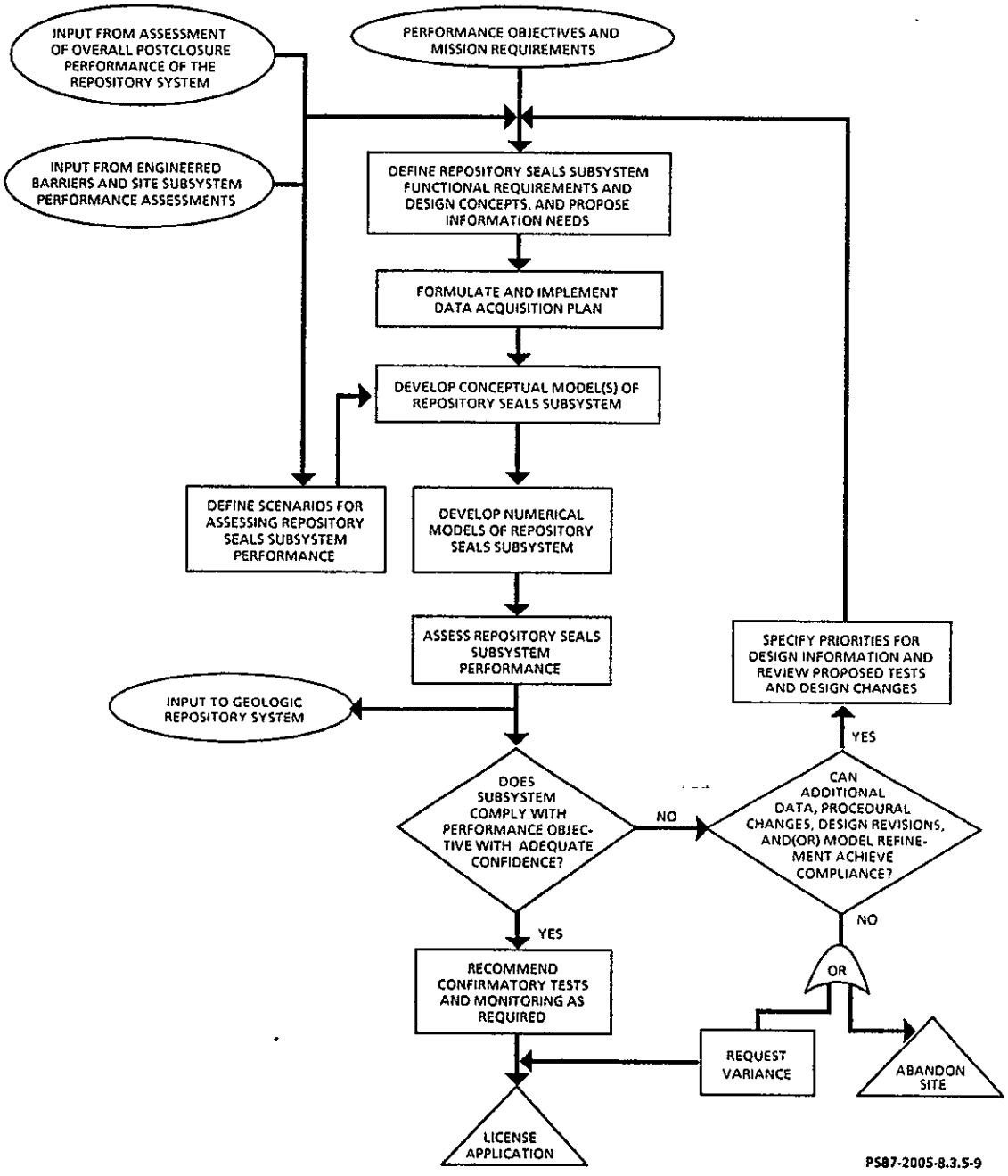

Figure 8.3.5-11. Repository seals subsystem postclosure performance assessment.

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development and refinement of the conceptual models with respect to the geometrical representation of the waste package will continue throughout the waste package design process.

8.3.5.2.1.3.2 Numerical model development.

At the present time, container corrosion analyses have relied on the use of an empirically derived correlation model of uniform corrosion. During FY 1987, the development of a mechanistic corrosion model will continue (see Section 8.3.4.5). A schedule for documentation, verification, benchmarking, and validation of the models used for assessing engineered barriers performance is provided in Sections 8.3.5.4 and 8.3.5.5.

8.3.5.2.1.3.3 Assessing engineered barriers subsystem performance.

An analysis of radionuclide release and transport from the engineered barriers subsystem for the conceptual design will continue. Relevant model parameters will be identified through sensitivity analysis. Plans for conducting performance assessments and sensitivity analysis in support of the advanced conceptual design and license application design were discussed in Section 8.3.4.5.2 and in Yung (1987). A radionuclide source term representing spatially distributed waste packages will be developed to assess compliance with subsystem requirements and for use in total system analyses.

8.3.5.2.1.3.4 Subsystem performance allocation.

Plans for future development of the methodology that will be used to assess postclosure performance of the engineered barriers subsystem are provided in the Performance Assessment Plan for the Basalt Waste Isolation Project (WHC, 1987).

8.3.5.2.2 Plans for assessing repository seals subsystem performance

The repository seals subsystem is defined as engineered materials and components installed to limit radionuclide transport to the accessible environment through pathways (e.g., excavations and damaged rock surrounding these excavations) created by repository construction. Such pathways would include shafts and boreholes (vertical openings) drilled from the land surface and horizontally extending entry and ventilation drifts linking the shafts and the waste emplacement rooms. The repository seals subsystem would also include seal materials placed in boreholes drilled from the underground facility, provided that such boreholes could become preferential pathways for radionuclide migration.

The seals placed in horizontal entries and ventilation drifts are designed to restrict the flow of potentially contaminated groundwater towards the repository shafts and thus toward the accessible environment. The function of the shaft and borehole seals is to restrict radionuclide migration, for example, by restricting the vertical flow of groundwater.

The sealing backfill materials will likely be a mixture of crushed basalt and bentonite clay. Pressure grouting for sealing fractures and (or) excavating damaged rock may be used to prevent the host rock surrounding the underground openings from becoming a preferential pathway for groundwater flow. Materials in addition to the crushed basalt and bentonite clay mixture may be used in the repository seals subsystem to ensure redundancy, to control potential groundwater seepage during construction, or to provide temporary or permanent structural support of other seals components.

Detailed strategies and methods for design, fabrication, and installation of shaft and borehole seals will be developed in conjunction with advanced conceptual and license application design activities (see Sections 8.3.3.3 and 8.3.3.4).

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8.3.5.2.2.1 Conceptual model(s) for repository seals subsystem

Acceptable conceptual models of the repository seals subsystem must adequately represent the process of radionuclide transport due to both diffusion and advection. The advection representation shall include advection induced by natural hydraulic gradients and by hydraulic gradients due to the density disparities created by the radiogenic heat. The conceptual models will include approximations of the potential pathways for radionuclide migration through the repository seals subsystem to the accessible environment for both nominal and disruptive conditions. The transport processes considered by the conceptual models are discussed in Section 8.2.2.

The potential transport pathways through the seals subsystem are (1) seal materials (e.g., crushed basalt and bentonite mixtures) that are placed within the excavated openings created by construction of shafts, drifts, and boreholes and (2) the rock zone around the excavated openings that has been damaged or disturbed by repository construction (see Fig. 8.3.3.1-3 and 8.3.3.1-5). Such pathways to the accessible environment include zones with potentially diverse physical, hydraulic, and sorptive properties (see Section 8.2.2.1.12).

To adequately represent the subsystem, the geometries and transport properties of these zones must be addressed by the repository seals subsystem conceptual models. These models will need to account for the following:

- The variation of transport properties in the zone of rock disturbed by excavation.
- The properties of the repository seals materials installed to fill the construction openings.

- The effects of potential gaps between the installed seals materials or backfill and the damaged host rock.

- Properties of the grout installed between the shaft liner and the wall of the excavation.

For example, the conceptual model used in support of the Hanford Site Environmental Assessment (DOE, 1986a) assumed a one-dimensional pathway for radionuclide migration through the damaged annulus of rock around the shafts and around the access drifts connecting the shafts to the emplacement rooms. This assumption was chosen in lieu of a pathway through the backfill material placed in the excavated openings at the time of closure. In Seitz et al. (1986), the sensitivity of radionuclide transport to this assumption was quantified. A two-dimensional model was used in this analysis. Pathways to the shaft through the damaged rock and through the sealing backfill in the entry drifts were considered.

Conceptual models must include phenomena that are important in determining groundwater flow and radionuclide migration through the seals subsystem and that are controllable by engineered design. In addition, they must include the boundary conditions that represent the environment within which the repository seals must function but that are not controllable by design. Examples of parameters controlled by design are hydraulic conductivity and effective porosity of the sealing materials placed within the shafts and boreholes. Examples of parameters that affect seal system performance but are not controlled by design include hydraulic conductivity and effective porosity of the host rock.

The hydraulic conductivity and effective porosity in the annulus of the damaged rock surrounding the excavated openings are likely to be larger than corresponding values in the undisturbed host rock (Kelsall et al., 1982; LBL, 1983). The difference is attributable to absorption of mechanical energy and redistribution of existing tectonic stresses during the construction process. Current conceptual models of the repository seals subsystem address the variation of hydraulic conductivity with radial distance from the excavated rock surface (Kelsall et al., 1982; LBL, 1983). Future modeling studies will analyze stress redistribution, the effects of construction and excavation techniques, and thermomechanical and thermochemical effects in the annulus of damaged rock surrounding an excavated opening. These results will be used to determine hydraulic properties for the estimated extent of the damaged rock (see Section 8.3.3.5). The development of the basic constituent model used to perform these analyses was discussed in Section 8.3.2.5. The DOE plans to refine these models based on in situ stress and hydraulic conductivity information obtained during site characterization.

Test results (Section 8.3.3.3.1) will be evaluated to assess the possibility of high groundwater flow rates through gaps between sealing materials and the excavated rock surfaces. This effect is presently anticipated to be small if swelling clays are used in the backfill.

The adoption of one or more preferred conceptual models will be based on expert opinion through a formal peer review process and will consider available data pertinent to repository seals subsystem performance. Such data will include the mechanical, chemical, and hydraulic states of the subsystem and the changes in those states.

8.3.5.2.2.2 Developing mathematical and numerical models of repository seals subsystem

Mathematical models and numerical codes for computer simulation of groundwater flow rates, flow paths, and radionuclide transport through the repository seals subsystem have been developed. Their continued refinement is planned (Sections 8.3.5.4 and 8.3.5.5). At the present time, the preferred method of analysis for assessing repository seals subsystem performance is deterministic rather than stochastic. This is based on preliminary analyses showing that less than 1% of the total radionuclides released at the accessible environment will migrate through the repository seals subsystem. A stochastic model will be developed for the final advanced conceptual design analysis and for performance assessments of the license application design (see Section 8.3.3.5).

Computer simulations of the repository seals subsystem will use specialized versions of the general-purpose MAGNUM-2D, CHAINT, REPREL, PORMC, PORFLO, and PORFLO-3D computer codes. (Descriptions of these computer codes are in Sections 8.3.5.4 and 8.3.5.5.) These computer codes will allow the needed flexibility for analyses of seals subsystem performance. A discussion of these codes as they relate to the modeling of the seals subsystem is provided in Section 8.3.3.5.2.

The need for a three-dimensional model of the repository seal subsystem has become apparent, based on preliminary analyses. Preliminary analyses have been performed using two-dimensional models. Assumptions were made during these analyses to simplify the true three-dimensional nature of the subsystem. For example, in the study by Seitz et al. (1986), a unit-thick vertical section through a single shaft, access drifts, and two waste-emplacement rooms (Fig. 8.3.5-12) were assumed. Use of this two-dimensional approach does not allow for radionuclide flux perpendicular to the vertical cross section modeled (i.e., radial component of the horizontal boreholes). Although the results to date are assumed to be conservative, this can only be confirmed through a more detailed three-dimensional analysis. Additional comments on the need for three-dimensional modeling of the repository seals subsystem are provided in Section 8.3.3.5.2.

8.3.5.2.2.3 Schedule and plans for assessing repository seals subsystem performance

The scope of planned work for enhancing the seals subsystem performance assessment analyses includes the following:

- Model and code development.
- Documentation and testing of computer codes and models.

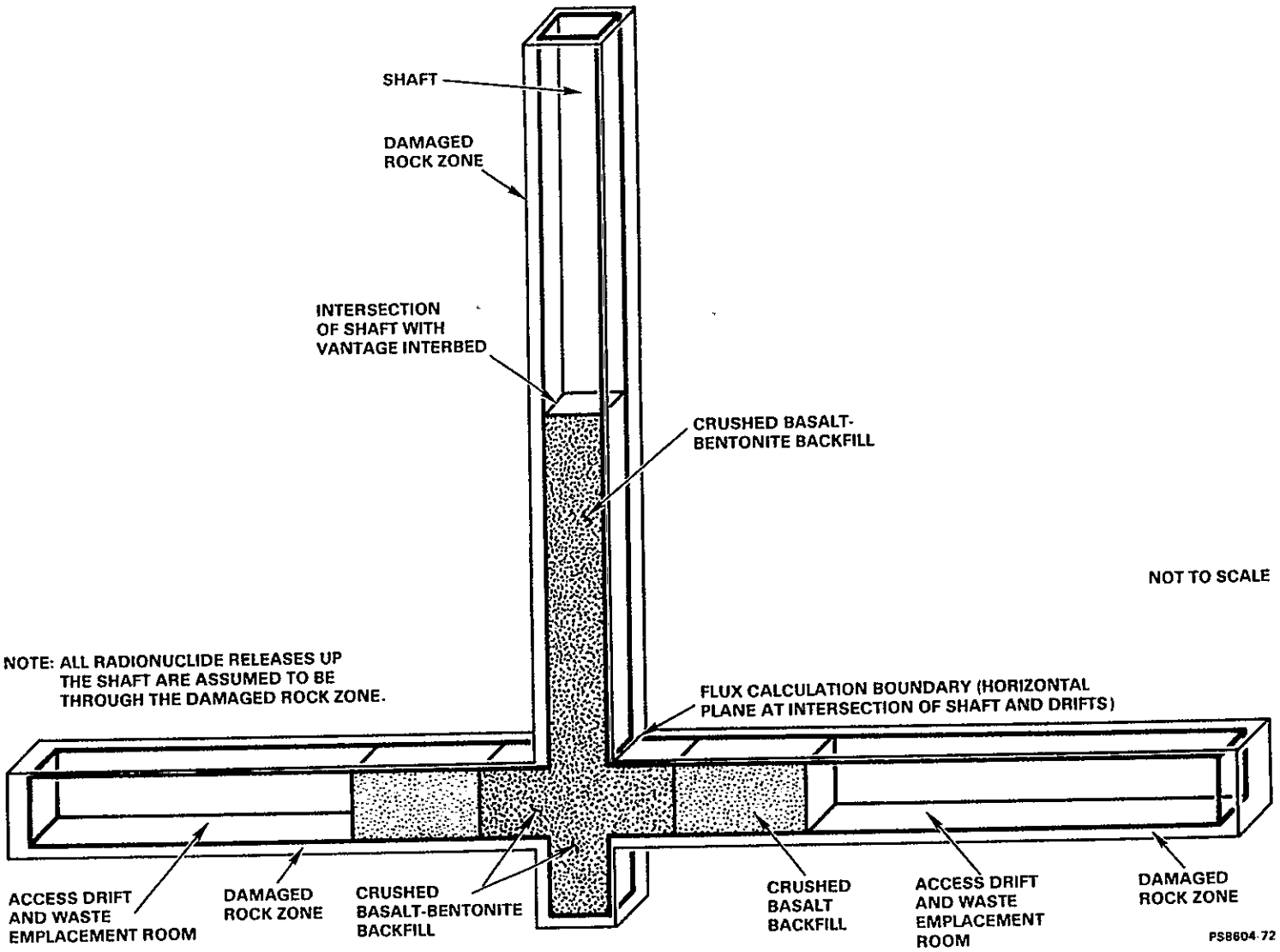

Figure 8.3.5-12. Two-dimensional seals subsystem configuration assuming a unit-thick vertical section through a single-shaft, access drifts, and two waste emplacement rooms.

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- Control of data used in support of analyses.
- Application of models.
- Interpretation of results.
- Use of interpreted results to guide design and collection of data, including recommendations for confirmation testing.

The scope of planned work will be discussed in terms of performance assessment activities as shown in Figure 8.3.5-11. Plans for future development of the methodology that will be used to assess postclosure performance of the repository seals subsystem are provided in WHC (1987).

8.3.5.2.2.3.1 Conceptual model development.

Computational models and conceptual modeling of the repository seals subsystem are well advanced. Work remains (1) on conceptualization and (or) characterization of the damaged rock surrounding the excavated openings and (2) on the refinement of the conceptual models representing the repository geometry. Conceptualization and (or) characterization of the damaged rock zone will result during exploratory shaft drilling and subsequent field studies. The assumptions presently used to model the damaged rock zone will be reviewed in terms of the constituent model developed for basalt (see Section 8.3.2.4). Conceptual models must also be developed to address disruptive scenarios and possible barrier degradation. The development and refinement of conceptual models on the geometrical representation of the repository seals will continue throughout the design process.

8.3.5.2.2.3.2 Numerical model development.

Primary emphasis is currently placed on the development of a three-dimensional model suitable for analysis of the repository seals system. A primary requirement of this model is the need to model the three coupled processes of groundwater flow, heat transfer, and mass transfer. The computer code PORFLO-3D is being developed to satisfy this need.

The need to develop a stochastic computer code for performance assessment of the seals has also been identified (see Section 8.3.3.5.2). Plans include use of this code to support performance assessment of the final advanced conceptual design and subsequent assessments of the seals license application design.

Additional development plans for PORFLO and PORFLO-3D include the incorporation of the capability to model discrete features such as shafts, boreholes, and dense fracture zones or faults. The addition of this capability is expected to significantly reduce the complexity of the conceptual model used to numerically simulate repository seals performance. This is assumed to be necessary for the seals subsystem to be modeled in three dimensions (see Section 8.3.3.5.1).

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A schedule for documentation, verification, benchmarking, and validation of the codes and models used in support of the repository seals subsystem performance assessments (MAGNUM-2D, CHAINT, PATH-2D, PORFLO, and PORFLO-3D) is provided in Sections 8.3.5.4 and 8.3.5.5.

8.3.5.2.2.3.3 Seals subsystem performance assessment.

An analysis of the release and transport of radionuclides from the repository seals subsystem for the conceptual design will be performed. Relevant model parameters will be identified through sensitivity analysis. Plans for sensitivity analysis in support of the advanced conceptual design and license application design are discussed in Section 8.3.3.5.2 and in Seitz (1987). In addition, a plan for performing seals subsystem analysis in support of the advanced conceptual design and license application design was discussed in Section 8.3.3.5.3.

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8.3.5.2.3 Plans for assessing site subsystem performance

The site subsystem is the set of natural geologic barriers extending from the boundaries of the engineered barriers and repository seals subsystems to the accessible environment. The site subsystem consists of the Cohassett flow interior; the overlying flow top; and the sequence of basalt flow interiors, flow tops, and interbedded sediments through which radionuclides could migrate to the accessible environment.

Based on current knowledge (DOE, 1986a), the Cohassett flow interior where the waste will be emplaced is expected to contribute significantly to the isolation performance of the repository. The dominant mechanisms that could potentially transport radionuclides from the waste packages to the accessible environment are (1) groundwater flow within basalt flow tops, (2) upward flow of groundwater through basalt flows, (3) crosscutting faults or tectonic fractures, or (4) a combination of the above (Fig. 8.3.5-13). Dispersivity and radionuclide retardation are also important site subsystem characteristics relative to radionuclide transport along groundwater flow paths (see Section 8.2.2.1.1).

Of the three subsystems comprising the geologic repository system (i.e., engineered barriers, repository seals, and site), site subsystem performance is the most critical to overall long-term repository performance. The primary function of the site subsystem is to limit the release of radionuclides to the accessible environment. The principal postclosure performance issues that affect site subsystem performance assessment are as follows:

- Issue 1.1--Releases to accessible environment.
- Issue 1.2--Individual protection.
- Issue 1.3--Ground-water protection.
- Issue 1.6--Ground-water travel time.
- Issue 1.8--NRC Siting Criteria.
- Issue 1.9--DOE guideline findings.

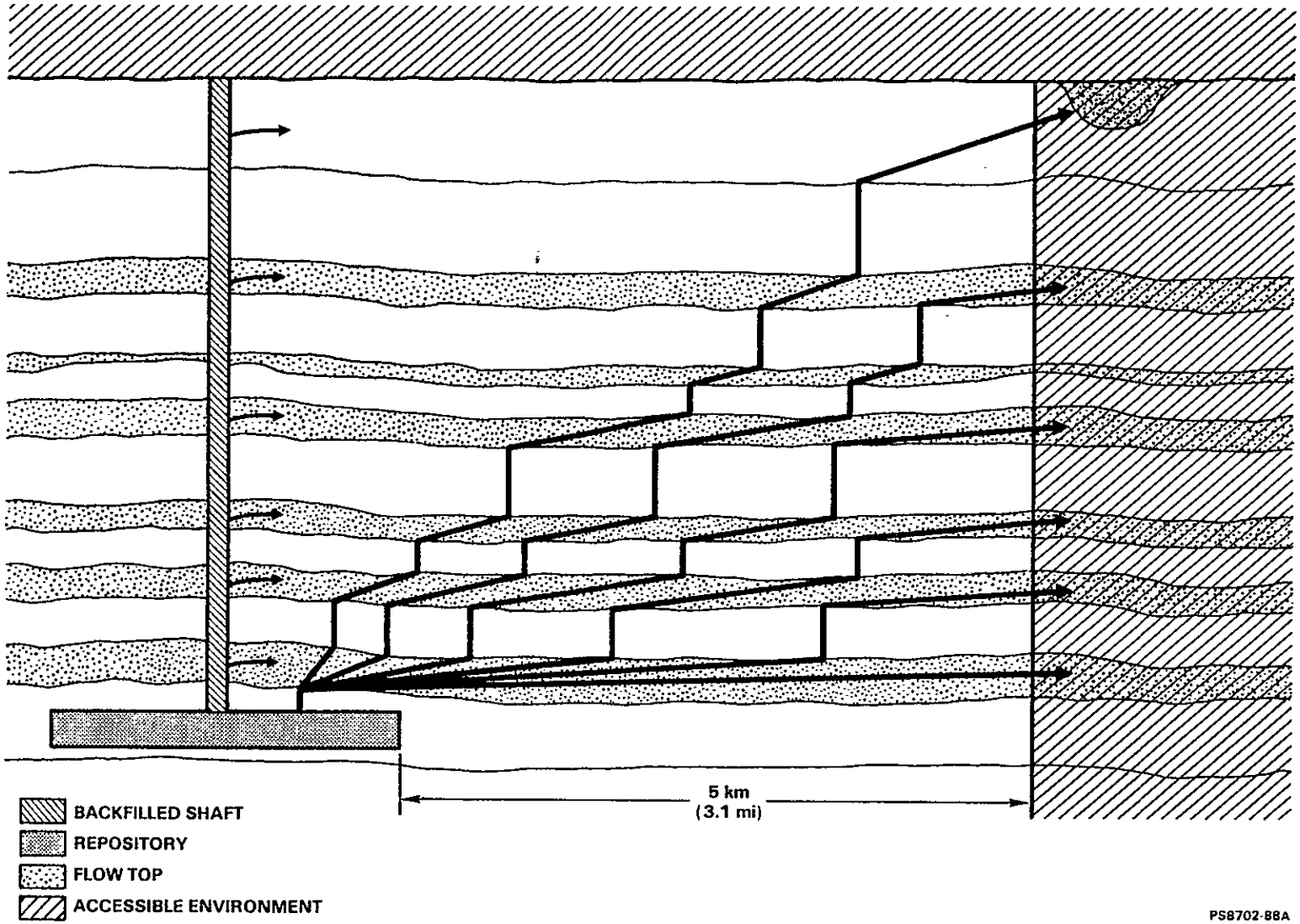

Figure 8.3.5-13. Schematic representation of the Hanford Site mined geologic repository system.

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The strategy for performance issue resolution is provided in Section 8.2.2. The performance objectives with which the site subsystem must comply are listed in Table 8.3.5-2. As shown in Figure 8.3.5-14, performance prediction studies will be conducted based upon data collected in site characterization activities. Sensitivity of predicted performance to changes in various site parameters will guide subsequent testing in the characterization program. For example, studies are planned to evaluate the sensitivity of a postulated, large-scale tectonic feature on groundwater flow dynamics in the Cold Creek syncline area (Khaleel, 1987b). Studies are also planned to consider and evaluate a set of alternative conceptual models of groundwater flow within the controlled area study zone (Mease, 1987). Thus, the development of a groundwater flow system conceptual model and numerical models used to assess performance will be an iterative process during site characterization.

8.3.5.2.3.1 Conceptual model(s) of the site subsystem

As part of the process of assessing performance, a set of qualitative concepts (site subsystem conceptual models) describing the nature, processes, and characteristics of the site subsystem are evolving. Knowledge of the fundamental nature of the phenomena and controlling features of the site subsystem are derived from interpretations of geologic, hydrologic, hydrochemical, and geochemical site characterization data. Preparing and using alternative conceptual models to assess the performance of the site subsystem serve three main purposes:

1. Test alternative hypotheses about the groundwater flow system.

2. Guide data collection during site characterization.

3. Form a basis for the repository performance-prediction modeling studies used to resolve the performance issues that drive site subsystem performance assessment.

The plans for developing and selecting hydrogeologic conceptual model(s) for the site subsystem differ from analogous plans for the engineered barriers and repository seals subsystems. For example, conceptual models of the engineered barriers subsystem will be based on engineering design concepts, whereas site subsystem conceptual models will be based on an understanding of the existing site-specific geologic and hydrologic setting. Design changes will alter the conceptual models of the engineered subsystems. In contrast, opportunities for altering the site subsystem are limited to such activities as relocating portions of the facility.

Current uncertainty in interpreting available data permits more than one site subsystem conceptual model to be inferred. Additional data are necessary to reduce uncertainty and identify, from among several alternatives, the conceptual model(s) ultimately judged to be most plausible. The plan for defining, assessing, and selecting conceptual models is documented in Mease (1987). Hydraulic stress test results will be used (Long, 1987) to confirm or refute various hypotheses of the site conceptual model.

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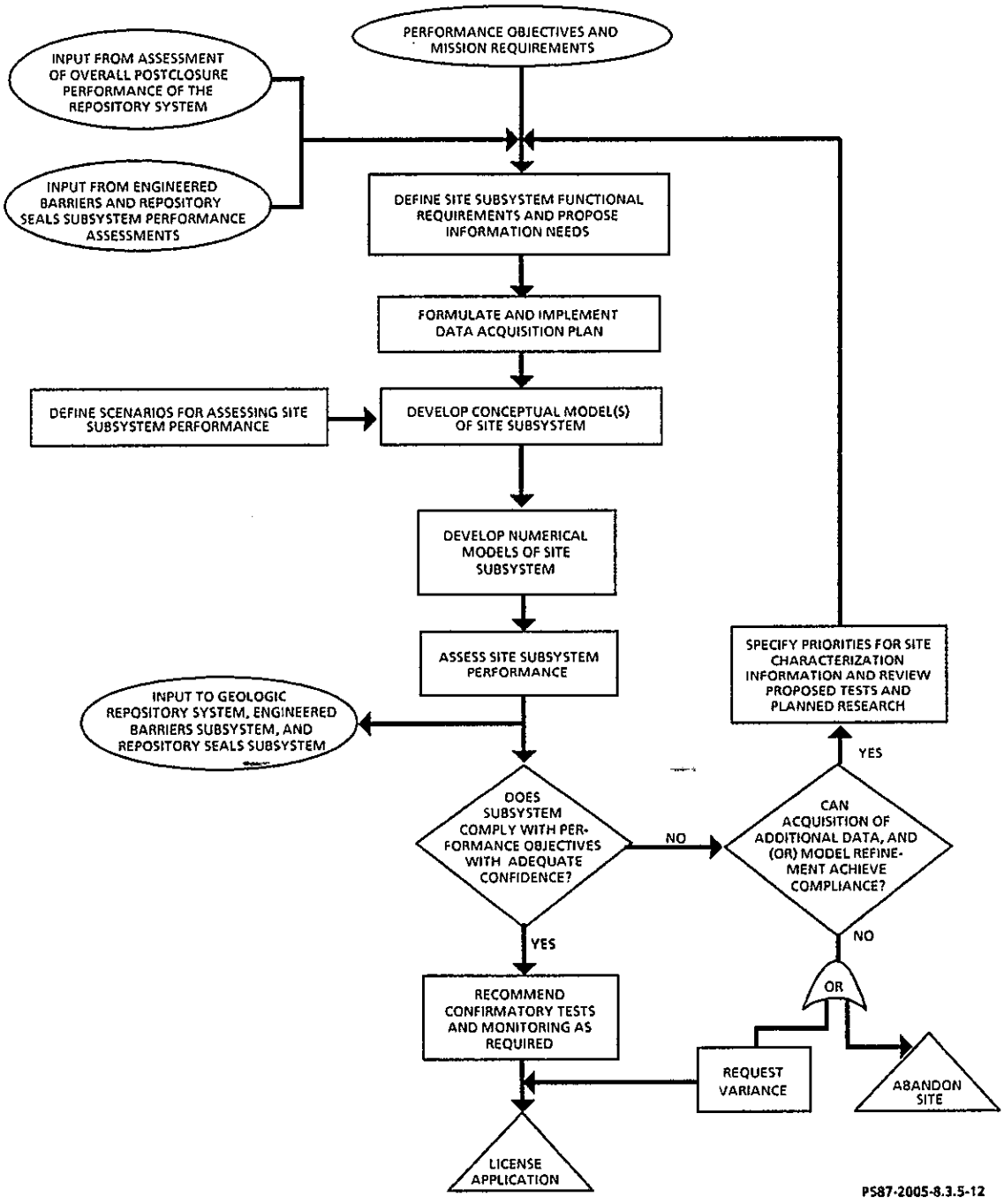

Figure 8.3.5-14. Site subsystem postclosure performance assessment.

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The basic elements of all geohydrologic conceptual models include identification and qualitative description of the following:

- Subsystem geometry.
- Major hydrostratigraphic units.
- Major stratigraphic and (or) structural features.
- Material property variability.
- Areas of groundwater recharge and discharge.
- Principal groundwater flow directions at local and regional scales.
- Scale and effects of man-caused groundwater withdrawal and recharge.
- Potential changes of groundwater flow patterns and hydrogeologic property distributions caused by natural processes and (or) events (see Section 8.2.2.1.1).

As discussed in Chapters 2 and 3, the basalts beneath the controlled area study zone and vicinity are composed of an extensive sequence of basalt flows with some sedimentary interbeds in the upper part of the section. The Sentinel Bluffs sequence of the Grande Ronde Basalt is designated the primary isolation zone and contains the Cohassett flow, which is the repository candidate horizon. A typical basalt flow within the controlled area study zone consists of a vesicular-to-brecciated flow top; a relatively dense, fractured basalt flow interior; and a glassy, chilled base. Specific geologic structures in the controlled area study zone are the Umtanum Ridge-Gable Mountain and Yakima Ridge anticlines and the intervening Cold Creek syncline. All are elements of the Yakima Fold Belt structural subprovince of the Columbia Plateau. A north-south trending geophysical anomaly (the Yakima Barricade anomaly), which is interpreted to be either a fault or a monocline, crosses the Cold Creek syncline in the northwest sector of the controlled area study zone (see Section 3.9.1.2.3).

A discussion of the basic features of the groundwater conceptual model is presented in Sections 3.9.3 and 3.9.5. The conceptual model features that are potentially most significant for site performance assessment are as follows:

- Flow path through (1) discontinuities within flow interiors, (2) flow contacts and sedimentary interbeds, and (3) bedrock structures (see Section 3.9.3.1.2).
- Low horizontal hydraulic gradients and resulting uncertain horizontal groundwater flow direction within the Wanapum and Grande Ronde Basalts (see Sections 3.9.3.2.1 and 3.9.1.2.3).

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- Potential for upward vertical movement of groundwater from the Grande Ronde Basalt to the overlying Wanapum Basalt (see Sections 3.9.3.2.2 and 3.9.3.3.2).

- Indications based on hydrochemical data of vertical mixing of groundwaters from several strata (see Section 3.9.5.2.2.1).

- The possibility that regional structures such as the Cold Creek hydrologic flow impediment and the anticlines might induce the upward flow of groundwater.

One of the intermediate goals of site characterization is to establish a defensible conceptual model or at least a very limited number of alternative conceptual models. For purposes of preliminary site subsystem performance assessments, alternative conceptual models are being evaluated. The four different models used in calculating groundwater travel time for the Environmental Assessment (DOE, 1986a) are examples of alternative conceptual models used in performance assessments. Those models represented a range of conditions from zero vertical flow to relatively high vertical flow. The approach of considering alternative conceptual models in preliminary performance assessments will continue and will be refined as additional data are obtained and a better understanding of the groundwater flow system develops.

Some of the elements of alternative groundwater flow conceptual models that will be considered in preliminary performance assessments include the following:

- Alternative horizontal flow directions.

- Higher than expected vertical flow rates, possibly resulting from significant tectonic breccia zones in the synclinal area.

- Vertical movement through sections exceptionally fractured or thin basalt flow dense interiors.

The effects of disruptive scenarios will be considered in conducting the site portion of the overall system performance assessment (Section 8.3.5.2.4).

Site subsystem performance assessment will include site performance sensitivity and parameter studies of potential site subsystem disruptive scenarios. The potential impacts of such scenarios on site performance will be provided to the overall system performance assessment activity. This information, together with the probabilities of occurrence, will be used in system performance assessment in developing the complementary cumulative distribution function for resolution of Issue 1.1.

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One purpose of planned site characterization activities is to determine which concept(s) of vertical groundwater flow is ultimately most representative (particularly of the upper Grande Ronde Basalt) in the vicinity of the candidate site. Examples of factors determining this include the following:

- Lateral continuity of individual basalt flows.
- Nature and frequency of tectonic fractures and faults.
- Influence of anticlinal structures.
- Strike and dip of the basalts.

As additional data are obtained, alternative conceptual models will be modified and refined and eliminated or added, as appropriate. This process will continue until a small number of clearly defined conceptual models are obtained that are consistent with the data.

An important aspect of the site conceptual model is the treatment of basalt either as a continuum (i.e., an equivalent porous medium) or as a medium having discrete fractures as its primary groundwater flow paths. A continuum approach to modeling flow through a fractured medium can only be justified if it can be demonstrated that an equivalent porous medium that has the same flow properties as the real discrete fracture system can be defined. For those cases in which an equivalent porous medium approach cannot provide an adequate representation of a fractured medium, discrete fracture models such as those described by Wilson and Witherspoon (1970), Long et al. (1982), Dershowitz (1984), Rouleau (1984), and Smith et al. (1985) must be used; these models simulate flow in each individual fracture of the network. However, a discrete fracture modeling approach requires detailed information on the geometry of the fracture system and, thus, may require an excessive amount of data and computational effort. The advantage of the continuum approach is that it requires only lumped estimates of hydraulic properties such that requirements for detailed fracture geometry and hydraulic properties for each fracture are avoided. The continuum approach is preferable if its use can be justified in modeling fluid flow and radionuclide transport through a fractured medium.

The use of an equivalent porous medium approximation in modeling fluid flow through the fractured basalt dense interiors has been specifically examined (Khaleel, 1987c). A simple model consisting of a discrete interconnected network of hexagonal colonnades was used. Results of the numerical simulation of flow through the discrete networks for basalt interior suggest that an equivalent porous medium approximation is appropriate for a continuous, interconnected network of hexagonal columns with uniform apertures. For distributed apertures, slight deviations from an equivalent porous medium behavior were apparent in polar plots of individual realizations.

It should be emphasized that this study considered only the primary cooling fractures of the dense interiors. At the very near-field scale (i.e., few meters to tens of meters) considered in the study, a model comprised of an interconnected network of filled fractures may be a reasonable representation

of flow through the dense interiors. At the near field (i.e., few hundred meters to a kilometer) and far field (i.e., regional scale of several kilometers), the effects of the primary cooling fractures may be overshadowed by the possible presence of tectonic features. Depending on the size and spacing of these tectonic features, the modeling of fluid flow and transport for the near and far fields can generally be accomplished by building these discrete features into a heterogeneous continuum model.

Preliminary equivalent porous medium studies considered only the primary cooling fractures of the dense interiors. Similar evaluations will also be performed for the basalt flow tops (Khaleel, 1987a).

Numerical models described in Section 8.3.5.4.1 can be used to distinguish between fractured systems that can be treated as equivalent porous medium and those that must be treated as a collection of discrete fracture flow paths. For simulating fluid flows, equivalence is established in terms of fluid (Darcian) fluxes, whereas for simulating solute transport, equivalence is established in terms of solute travel time or residence time. A review of the literature suggests that some discrete fracture systems that may behave as an equivalent porous medium for fluid flux may not behave like a continuum for solute transport at the same scale. Analyses will be made to evaluate the equivalent porous medium approximation for transport through fractured basalts (Khaleel, 1987a).

The performance assessment role in evaluating conceptual models is to determine the performance differences among the alternatives. Lack of a performance difference between two alternative conceptual models would be a disincentive to determine which model is more correct. Conversely, a large performance difference between alternative models would provide an incentive to determine, through the characterization program, which is most nearly the correct representation of the site.

Details of the conceptual models and conceptual model evaluation process will be presented in the site groundwater study plan (see Section 8.3.1.3.3.3.2), the regional groundwater study plan (see Section 8.3.1.3.4.3.1), and the groundwater flow system hydrochemistry study plan (see Section 8.3.1.4.3.3.1).

8.3.5.2.3.2 Developing mathematical and numerical models for the site subsystem

The equations comprising subsystem mathematical models and the solution algorithms embodied in the computer codes must ultimately be integrated into quantitative representations (i.e., numerical models) of the site subsystem. Several important aspects of model development are discussed in this section.

The important processes, events, or conditions identified in the conceptual models are expressed in terms of mathematical equations based on accepted scientific principles and observed cause-and-effect relationships. The principles of conservation of mass, momentum, and energy form the basis for formulating the governing equations of the mathematical models.

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Phenomenological and (or) empirical relationships are considered in the context of one or more of the conservation principles to develop the specific equations of the site subsystem mathematical models and computer codes. An example of such empirical relationships is the use of Darcy's law to describe groundwater flow in a continuum. Groundwater flow in open fractures can be simulated by calculating an equivalent hydraulic conductivity (England et al., 1985, p. 4). The basalt can be modeled as either a porous or fractured medium. The current strategy is to model both the flow top and flow interior of the basalt layers as equivalent porous media; this strategy will be reviewed on the basis of results from planned studies on the applicability and limits of equivalent porous medium approximations (Khaleel, 1987a).

The mathematical equations describing flow and transport, and the approximations and assumptions they are based on, are given in the references for mathematical models and computer codes (Sections 8.3.5.4 and 8.3.5.5). The mathematical models are undergoing continuous review and are subject to revision. The impact of the assumptions used to derive the governing equations on subsystem performance is being evaluated in particular. Plans for expanding and refining the applicability of some of the site subsystem computer codes are discussed in Section 8.3.5.5.

Both deterministic (e.g., MAGNUM-3D, FECTRA) and probabilistic codes (e.g., PORMC-SF) will be used to evaluate the site subsystem. The deterministic codes will be used in interpreting data, guiding data collection, and focusing the application of the probabilistic codes to those areas where addressing uncertainty is most critical. Different codes representing different levels of sophistication will be used, depending on the specific objectives of a particular analysis. The output of the probabilistic codes will be used directly when assessing compliance with regulatory requirements in order to provide estimates of the calculation uncertainty. Because of the additional computation involved in calculating uncertainties, the probabilistic codes are generally simpler formulations (e.g., two-dimensional rather than three-dimensional, point source rather than distributed source of radionuclides). The deterministic codes may be used to support the probabilistic results in selected realizations of the set of probabilistic runs where the deterministic code may be more sophisticated than the probabilistic code. This will verify the applicability of the simplified elements of the probabilistic code. Additionally, deterministic codes will be emphasized in parameter sensitivity analysis. The type of analysis and level of code complexity (and related data collection requirements) applied to each analysis will be determined based on the specific requirements for assessing compliance with individual performance objectives.

Assessment of site subsystem performance with numerical models requires that important subsystem characteristics be described quantitatively. Specific values, or distributions, must be assigned to the parameters used in the numerical models. These parameters must be known or estimated in spatial and temporal terms to compute subsystem performance. A discussion of the information needs that relate to quantifying the specific parameters is presented in Section 8.3.1.3.3.

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An essential element of numerical model development is the formulation and implementation of a systematic method of quantitatively evaluating alternative interpretations of site-specific data and translating these data into a meaningful and consistent combination of input parameters. A quantitative representation is a quantitative extension of a qualitative conceptual model and consists of a specific combination of the parameters used in the computer code. Evaluation of alternative conceptual models and quantitative representations of those conceptual models is included in site subsystem performance assessment as a method of addressing model uncertainties (as opposed to parameter uncertainties). There will be one or more quantitative representations for each conceptual model.

The use of alternative representations to quantitatively depict the site subsystem in computer simulations meets several needs.

- The role of expert judgment, interpolation, and extrapolation in estimating spatial and temporal distributions of parameters from sparse, typically discrete measurements can be explicitly addressed.
- The fact that different interpretations of the same data can result in multiple representations of the site subsystem can be emphasized.
- A convenient and integrated framework is provided to determine priorities of proposed information requirements and to judge the value of proposed and completed tests in assessing repository performance.
- A practical, auditable, and logical means of evaluating and screening is facilitated for different interpretations of subsystem data.

The quantitative representations of parameters in a numerical model may be expressed as single values, ranges, or probability distributions for a given location and time. These representations depend on the nature of the parameter and the requirements of the mathematical model in which it is used. This flexibility facilitates the expression of uncertainty within the confines of each numerical model. In addition, each quantitative representation may have distributions or ranges of individual parameters that partially overlap those of other quantitative representations. However, the intent is to make each numerical model internally consistent and significantly different from other numerical models.

Once the preliminary simulations of site subsystem performance are completed, some representations may prove to be similar to others or internally inconsistent. Internal inconsistencies may include parameter combinations that violate mass balance constraints or parameter combinations that are not entirely consistent with some portion of the data base. Internal inconsistency would not always be evident during the initial development of a numerical model. Hence, redefinition, screening, or refinement of the set of models subsequent to preliminary performance assessments may be required.

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Site subsystem quantitative representations include numerical specification of the following:

- Extent of the disturbed zone around the repository and the locations of groundwater particle starting points for determining travel time.
- Location of the accessible environment boundary and, hence, the extent of the controlled area.
- Component geometries.
- Properties of the rock-water system within the model domain (e.g., effective porosity, hydraulic conductivity, specific storage).
- Locations and characters of model boundaries.
- Rates of groundwater recharge and discharge within the model boundaries.
- Locations, geometries, material properties (e.g., effective porosity, hydraulic conductivities, geochemical properties), and frequencies of features (e.g., crosscutting geologic structures) that may significantly affect groundwater movement and radionuclide transport.

The quantitative representations that are judged the most likely to be valid will be designated as input to the baseline numerical model(s) and will be used as the reference conditions to assess sensitivities and compare the relative effects of disruptive scenarios. The ability to establish a baseline model of the system may be impacted by characterization activities that may temporarily alter the hydrologic behavior of the site. An analysis will be conducted to assess the impacts of Exploratory Shaft Facility construction on groundwater transport.

8.3.5.2.3.3 Schedule and plans for assessing site subsystem performance

Site performance assessment consists of the following categories:

- Conceptual model and quantitative representation evaluation.
- Numerical model development.
- Scenario definitions.
- Site subsystem performance assessments.
- Subsystem performance requirements input.
- Performance confirmation recommendations.

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Under conceptual model evaluation, development of a set of alternative conceptual models suitable for performance assessment is planned. These conceptual models will be an update of the concepts used in calculating the groundwater travel times presented in the Environmental Assessment (DOE, 1986a) and will address the items mentioned in Section 8.3.5.2.3.1. These conceptual models will be updated before the performance assessments for both subsystems and the total system are made at the end of the advanced conceptual design phase. These assessments are needed to finalize the advanced conceptual design and to assign subsystem performance goals for license application design studies. Final update of conceptual models will occur before the site performance assessment needed for a potential license application is finalized. Throughout this process, conceptual models will be revised, added, or deleted from the set used for performance analysis. The decisions on which action to take will be made as additional information becomes available from site characterization and as the method of developing conceptual models matures.

As part of the activity for evaluation of quantitative representations, parameter sets will be developed for the advanced conceptual design performance assessment and updated for the license application performance assessment. These parameter sets are derived primarily from the corresponding site characterization data bases. Model validation activities (Section 8.3.5.3.4) are planned to support the license application performance assessment.

Disruptive event and process scenario definition and analysis fall within the total system performance assessment category. The site portion of the total system performance assessment is, for the most part, an extension of the site subsystem analysis, and most of the postclosure scenarios are expected to be site related. Further discussion of scenario development and implementation is found in Section 8.3.5.2.4.4.

The site subsystem performance assessments involve several major milestones. In the near term, a performance assessment of the conceptual design will be used to guide site characterization activities and to refine the plans presented in this site characterization plan. It will incorporate information developed from conceptual modeling and site characterization activities. A site subsystem sensitivity and uncertainty analysis will be conducted to support subsystem allocation. That analysis will determine the sensitivity of the site performance measure to various model parameters and will then estimate the propagation of model input uncertainty to uncertainty in performance. A site performance assessment study will be conducted in support of advanced conceptual design. An updated site performance assessment will then be conducted in support of a potential license application. These assessments will directly support evaluation of the site in terms of the site subsystem performance measures and will indirectly support evaluation of total system performance.

Some of the site characterization activities that will directly support the site conceptual design performance assessment activities are shown under site characterization on the site subsystem performance assessment schedule

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chart. Major milestones for site characterization correspond to major project milestones (e.g., advanced conceptual design and license application). Some additional milestone detail is shown for purposes of near-term planning. Pretest analysis of the large-scale hydraulic stress tests with the site performance assessment models and codes is expected to assist in rapid test interpretation and to link more closely the testing and performance assessment methods. Comparison of the large-scale hydraulic stress pretest predictions with actual data from the large-scale hydraulic stress tests at borehole RRL-2B immediately subsequent to completion of the tests is scheduled. This will serve as an element in model validation.

Recommendations for site confirmation activities would be issued concurrently with, or shortly after, issuance of the license application documentation.

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8.3.5.2.4 Plans for assessing system performance

The geologic repository system is defined as the set of natural and engineered barriers that control the release and migration of radionuclides to the accessible environment. The performance of the system depends on the performance of the engineered barriers subsystem, the repository seals subsystem, and the site subsystem.

The approach to assessing subsystem performance and using the results of those assessments to guide future work was described in Sections 8.3.5.2.1 through 8.3.5.2.3. The relationship of subsystem performance to system performance is illustrated in Figure 8.3.5-15. Because the geologic repository is a composite of the three major subsystems, system performance consists of integrating, in an appropriate way, the information from the subsystem performance assessments and then determining whether the overall system performance complies with the system performance objectives with adequate confidence. The primary interactions between subsystems are (1) the thermal effect of waste packages on groundwater flow through the site and (2) mechanical effects of shaft; drift; and borehole excavation on groundwater and, therefore, radionuclide pathways.

For the overall repository system, the principal objectives of planned performance assessment activities are as follows:

- Identify and characterize disruptive processes and events that may have a significant effect on performance.
- Integrate subsystem conceptual models into a unified set of system conceptual models that will be used to assess the overall repository system (inclusive of scenarios).

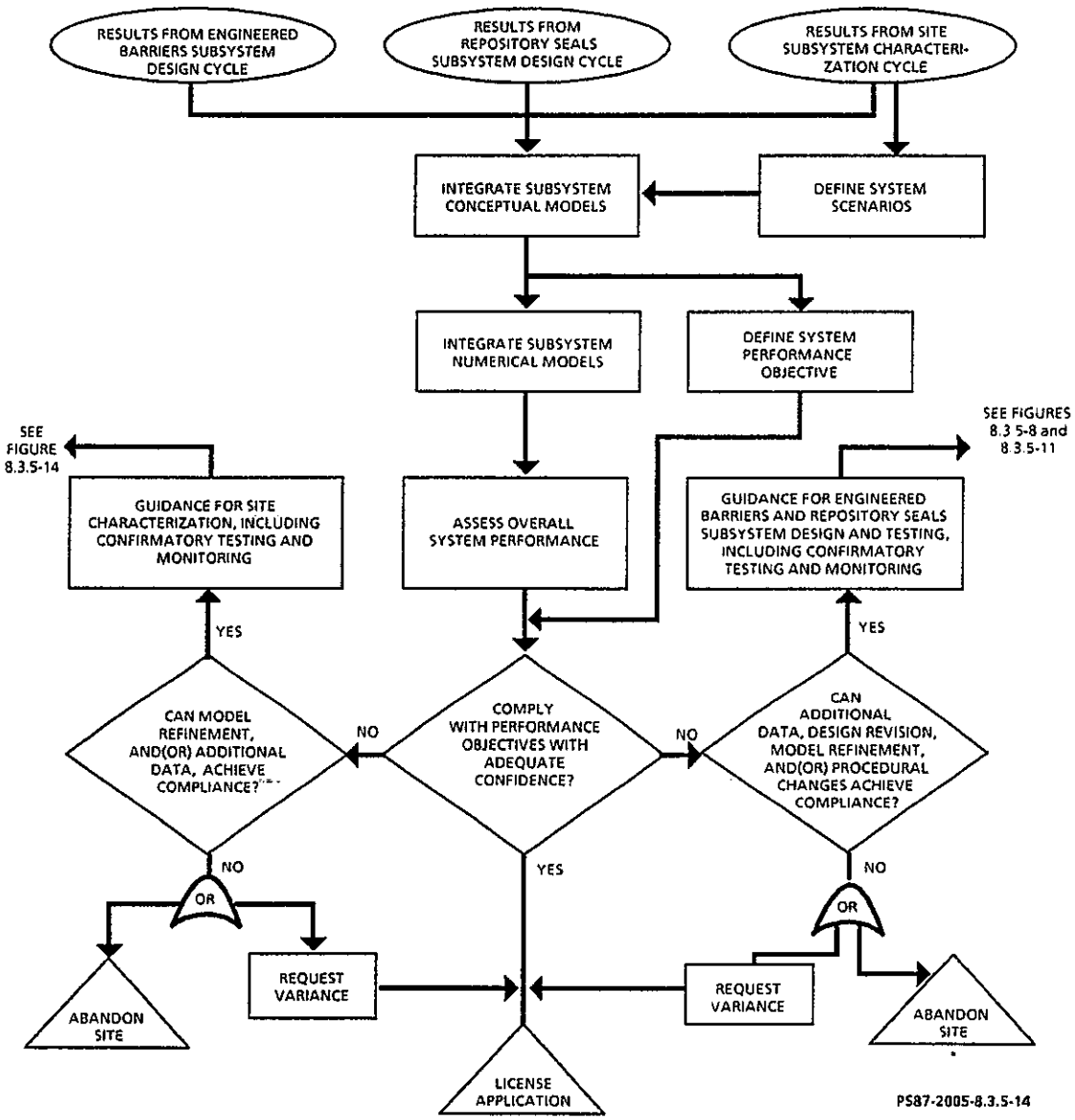

Figure 8.3.5-15. Overall postclosure performance assessment of the geologic repository system.

- Integrate subsystem mathematical models and computer codes into an appropriate system model.
- Prepare the numerical system model, taking into account appropriate model parameter information and all interdependencies of subsystem behavior.
- Predict postclosure performance of the overall system, considering all significant scenarios.
- Compare results with performance objectives to:
  - Establish suitability of the site.
  - Define nature and extent of additional work.
  - Provide input for comparative analysis.
  - Provide input for resolution of issues.

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8.3.5.2.4.1 Defining scenarios

Both the NRC (NRC, 1987a) and the EPA (EPA, 1986) mandate that credible events and processes affecting the geologic disposal system performance during its regulated life be factored into the performance assessment. In addition to the licensing requirements, the general guidelines for the recommendation of sites for the nuclear waste repositories (DOE, 1987a) impose further conditions regarding favorable and potentially adverse conditions. These potentially adverse conditions are discussed in Issue 1.8, NRC Siting Criteria.

In the proposed approach, shown in Figure 8.3.5-16, the basic performance assessment models developed for analyzing the nominal, nondisruptive case would be used for analyzing the consequences of disruptive events and processes. This approach assumes that mathematical descriptions of the basic processes (e.g., fluid flow, heat transfer, mass transport) would not change because of the disruptive processes and events. Values of the parameters, however, could change in these descriptions, and several different conceptual models may be required. Because of these changes, some modifications to existing models may be required. These could include special grid patterns to accommodate changed geometry and special numerical schemes that would be stable under widely varying parameter values representing the disruption scenarios. Obviously, the extent of modifications can only be assessed after the first step in the approach (i.e., that of sensitivity study) has been completed.

Potential disruptive events and processes have been identified (e.g., Arnett et al., 1980; Davis et al., 1983; Foley et al., 1982; Hunter, 1983; Rigdon et al., 1981; and Roberds et al., 1984). The principal thrust of these documented studies has been to list processes and events and tentatively rank them in terms of expected relative importance; only limited attempts have been made to characterize the system in its altered state and estimate releases from the disrupted system taking these processes and events into account.

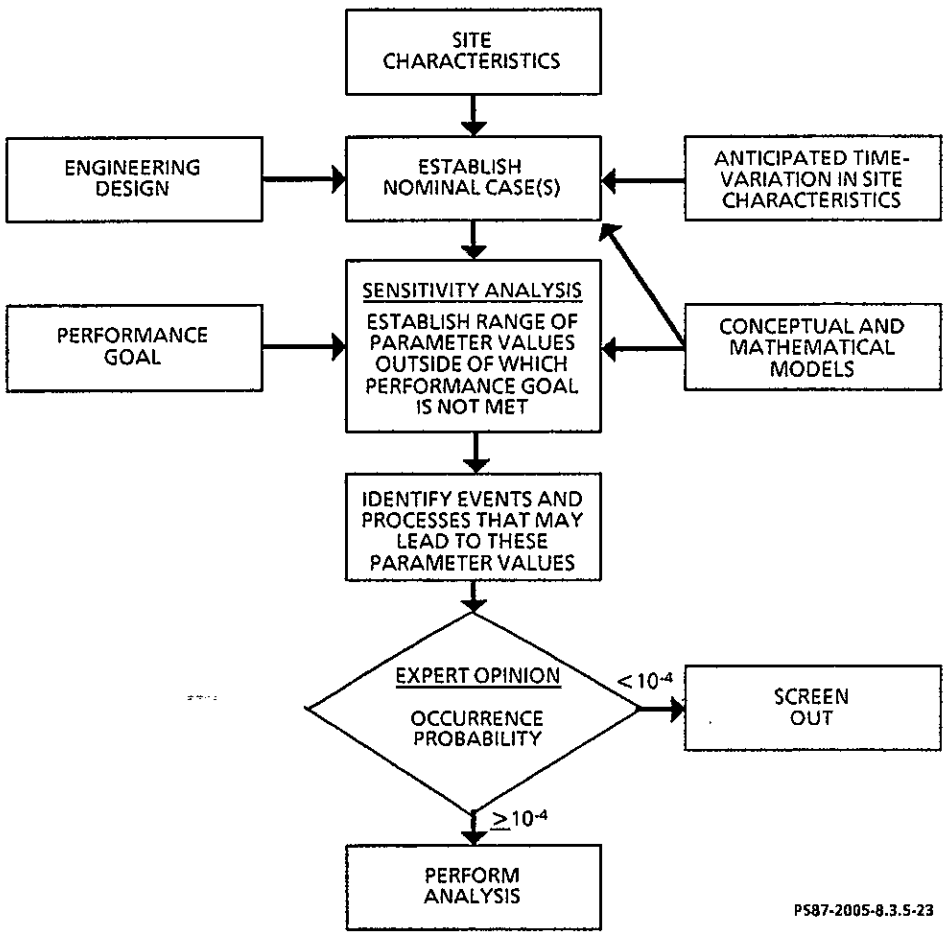

Figure 8.3.5-16. Scenario screening and selection process.

The various approaches to the identification of credible disruptive events and processes can, in general, be put into two broad categories. The first category includes those approaches based on the preparation of a comprehensive list of all physically possible events and processes that might occur in the time span under consideration. In the second category are approaches based on a sensitivity analysis of system performance to alternative conceptual models and physical properties that may be impacted by disruptive events and processes. The plan is to use the second approach because it restricts the requirements for supporting research to those areas that are sufficiently probable and sufficiently consequential to warrant attention.

Based on the existing data base for identification of potential disruptive events and processes, disruptive scenarios will be identified and screened through a combination of expert opinions and sensitivity analyses. The process is initiated with the performance of sensitivity analyses in which the consequences of prematurely breached containers and altered pathways (e.g., increased conductivity) are assessed. These analyses will provide insight into those parameters that most strongly affect releases to the accessible environment and insight into the magnitude of changes in these parameters causing a significant increase in releases. This information will provide a basis for identifying credible scenarios that may have a significant effect on system performance; these scenarios would be the principal focus for detailed characterization and analysis. Potentially significant scenarios are discussed in Section 8.2.2.1.1. In addition, the process for scenario selection and characterization will consider low probability scenarios with large consequences and high probability scenarios with low consequences.

Scenarios selected for detailed analysis will require the acquisition of information needed to develop conceptual models and support estimation of scenario probabilities. These conceptual models, and the resulting numerical models, will be used to assess the waste isolation capabilities of the natural and engineered barriers systems. The amount of data needed to verify a conceptual model and to make judgments of scenario probabilities will be determined by expert opinion.

If the required modifications to existing models prove extensive (in the sense that each modification represents a new model that would have to be verified and validated), a simplified system model may be developed expressly for the analysis of particular disruptive scenarios. Thus, while detailed models may be used to perform sensitivity analysis, simplified models may be used to assess cumulative release and associated probability from disruptive events and processes.

8.3.5.2.4.2 Integrating conceptual models

The conceptual model of the overall geologic repository system will be consistent with the engineered barriers, repository seals, and site subsystem conceptual models. In addition, the system conceptual models must account for interdependencies of parameters defining the processes and components of the subsystems comprising the system.

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All potential paths for the transport of radionuclides begin at the individual waste packages. Two pathways are presently considered.

1. From the waste package either directly to the site radially through the emplacement hole walls or axially through the emplacement hole into the emplacement rooms, tunnels, and drifts into the site subsystem and, ultimately, to the accessible environment.

2. From the waste package to the emplacement rooms and then into the repository seals subsystem and from the repository seals subsystem either directly to the accessible environment through the shafts and boreholes or through the damaged rock zones into the site subsystem.

From a system performance perspective, the engineered barriers subsystem conceptual models are compatible with the overall system conceptual model since both involve the release and transport of radionuclides (see Section 8.3.5.2.4 for system performance objectives). Similarly, the repository seals subsystem models are compatible with the system conceptual models since the performance measure for the subsystem is expressed in terms of radionuclide flux to the accessible environment. The primary difference lies in the fact that engineered barriers and repository seal subsystem models used in the system model must address the interdependence of the various subsystems more specifically than is required from a subsystem analysis perspective.

In contrast, the site subsystem conceptual models emphasize groundwater flow directions and velocities. Hence, the perspective for evaluation of the site subsystem within the context of the total system will be to (1) define a radionuclide source term, (2) augment the site subsystem conceptual models previously discussed with additional information on the physical and chemical interaction of the radionuclides with the host rock minerals and groundwater and (3) account for radioactive decay in order to assess radionuclide transport. As such, consideration of radionuclide transport through the site subsystem, in the context of the overall system, will include the following factors:

- Nature of the geologic media and groundwater flow field.

- Transport of radionuclides in this flow field by chemical or physical processes, radionuclide decay, and dispersion and diffusion effects.

The site subsystem conceptual models will be used in conjunction with the engineered subsystems conceptual designs and component specifications to describe the overall repository system. In addition, discrete and (or) probabilistic values of those transport and thermal parameters not previously needed for the subsystem performance assessments will be addressed for system conceptual modeling.

As engineered subsystem designs are refined and as site characterization provides additional site subsystem information, the system conceptual models will be adjusted accordingly. Preferred system conceptual models will be selected as needed in accordance with the schedule for assessing performance to develop and document engineered designs.

8.3.5.2.4.3 Developing an integrated mathematical and numerical system model

The equations comprising subsystem mathematical models and the solution algorithms embodied in computer codes must ultimately be integrated into quantitative representations (i.e., numerical models) of the geologic repository system. Several important aspects of system model development are discussed in this section.

There are basically three options available for developing a model of the total system: (1) a single complex distributed-parameter model that attempts to reproduce or simulate all governing processes in detail, (2) a system model that integrates appropriate subsystem results, or (3) a simplified lumped-parameter model that simulates the assumed primary or governing relationships. It is proposed that Options 2 and 3 be pursued, since a model based on Option 1 is generally excessively cumbersome and unnecessary for system analysis.

During the early stages of site characterization, the preferred approach will be to use a simplified lumped-parameter mathematical model. An example of a lumped-parameter system model is EPASTAT (Eslinger and Sagar, 1986). This model was used to evaluate the performance of the geologic repository in basalt (DOE, 1986a) and its continued use is considered appropriate due to the paucity of data and the assumed overall conservative nature of the model (see Section 8.3.5.4.2.2 for a brief description of EPASTAT). Another lumped-parameter code, SPAM, will be similar to EPASTAT but with the addition of a dose calculation algorithm. The limitations associated with using simplified lumped-parameter models in support of sensitivity analyses, etc., is recognized. As more data become available to support the use of more detailed models, detailed subsystem models will be integrated in a systems configuration as implied in Option 2.

Whether or not system mathematical models are of a distributed- or lumped-parameter type, they will be probabilistic in nature. Thus, uncertainties will be explicitly considered. Important inputs to either type of system model will generally be provided from the outputs of the subsystem models. As explained previously, the subsystem mathematical models eventually used for license application will, in most cases, be probabilistic; therefore, outputs will be in the form of probability distributions. For example, the radionuclide source term from the engineered barriers subsystem model will be in the form of either a multivariate probability distribution or a time-dependent stochastic process. Likewise, the travel time from the site subsystem model will be in the form of a probability distribution. These kinds of inputs to the system models will result in probabilistic system-model outputs that will allow results to be presented in the form of complementary cumulative distribution functions (i.e., the probability of not complying with the EPA cumulative release criterion).

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In developing system mathematical models, the fact that the three subsystems are not independent of each other will be taken into account. For instance, certain properties of the site subsystem (e.g., diffusion coefficients and porosities) have a central influence on estimates of the source terms from the engineered barriers subsystem. Therefore, the source terms from the engineered barriers subsystem analysis are conditional on these site subsystem properties. In developing the cumulative release curve for the overall system, this dependence will be considered.

The relationships among the mathematical models and computer codes that are currently planned for use in the license application are shown in Figures 8.3.5-17 through 8.3.5-19. The system assessment process will operate by different computational models when addressing the different performance objectives (see Table 8.3.5-2). As shown by Figures 8.3.5-17 through 8.3.5-19, different combinations of the mathematical models and computer codes will be used, depending on the specific performance criteria being addressed. (See Sections 8.3.5.4 and 8.3.5.5 for descriptions of mathematical models and computer codes.)

Assessment of system performance with numerical models requires that important subsystem characteristics be described quantitatively. Specific distributions will be assigned to the parameters used in the mathematical models described in the previous section. The importance of quantifying parameters in a systematic and consistent manner was discussed in Section 8.3.5.2.3.2.3. The quantification of parameters used to support the system model will be consistent with the quantification of parameters used to support subsystem models. The mathematical models and parameter quantification used in all analyses will be carefully controlled and fully documented and reviewed.

8.3.5.2.4.4 <u>System performance objectives</u>

The overall system performance objectives are addressed in Issues 1.1, 1.2, 1.3, 1.8, and 1.9. Strategies for resolution of these issues are discussed in Section 8.2.2. As discussed in these strategies, the system model will be used to assess the performance of the geologic repository against the requirements stated in these issues.

Detailed sensitivity analyses will be performed to evaluate the relative importance of the various barriers and processes that comprise the system. Once these analyses have been completed, the relative importance and performance will be compared against the assumed performance identified in the issue resolution strategies discussed in Section 8.2.2 for Issues 1.1, 1.2, 1.3, 1.8, and 1.9. In addition to these analyses, the performance of the system will be evaluated against the system performance objectives at the completion of both the advanced conceptual design and the license application design phases of site characterization.

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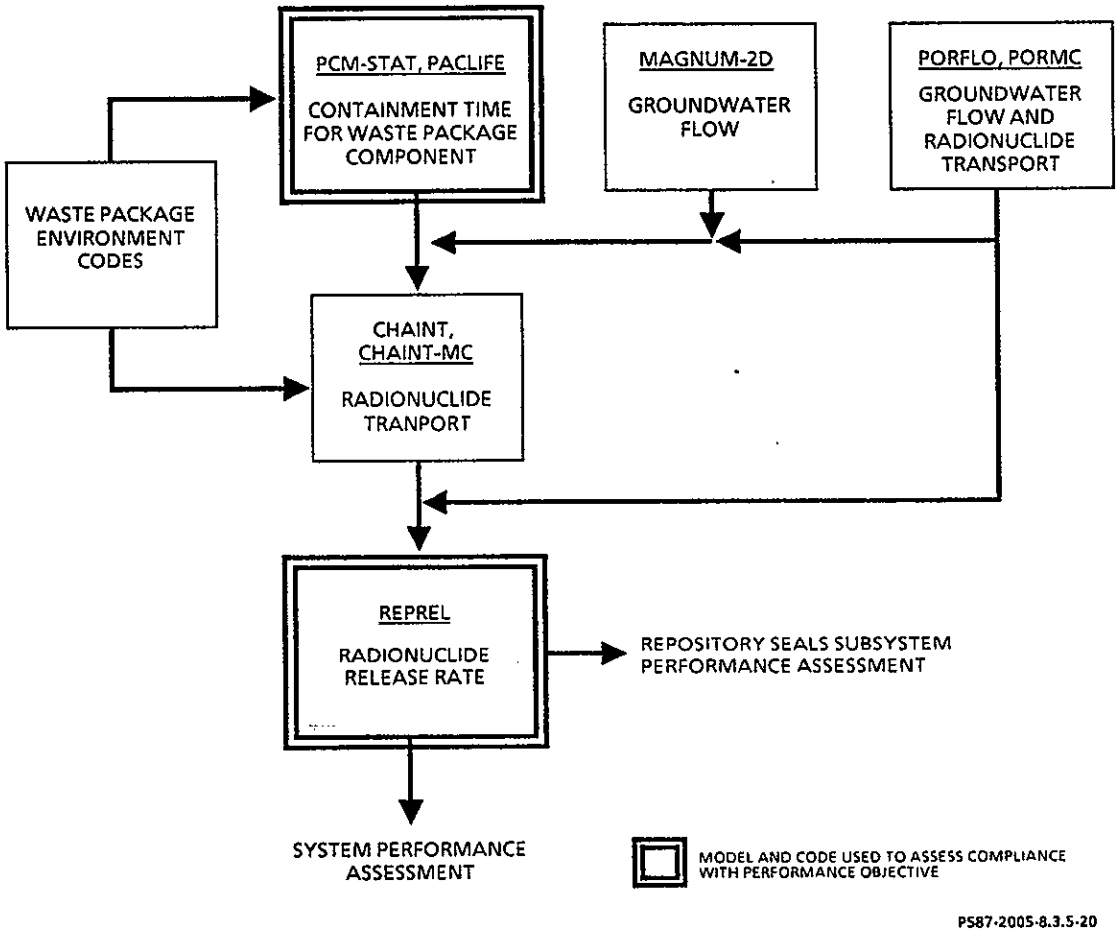

Figure 8.3.5-17. Codes for assessing engineered barriers subsystem performance. (See Sections 8.3.5.4 and 8.3.5.5 for descriptions of computer codes shown in this figure.)

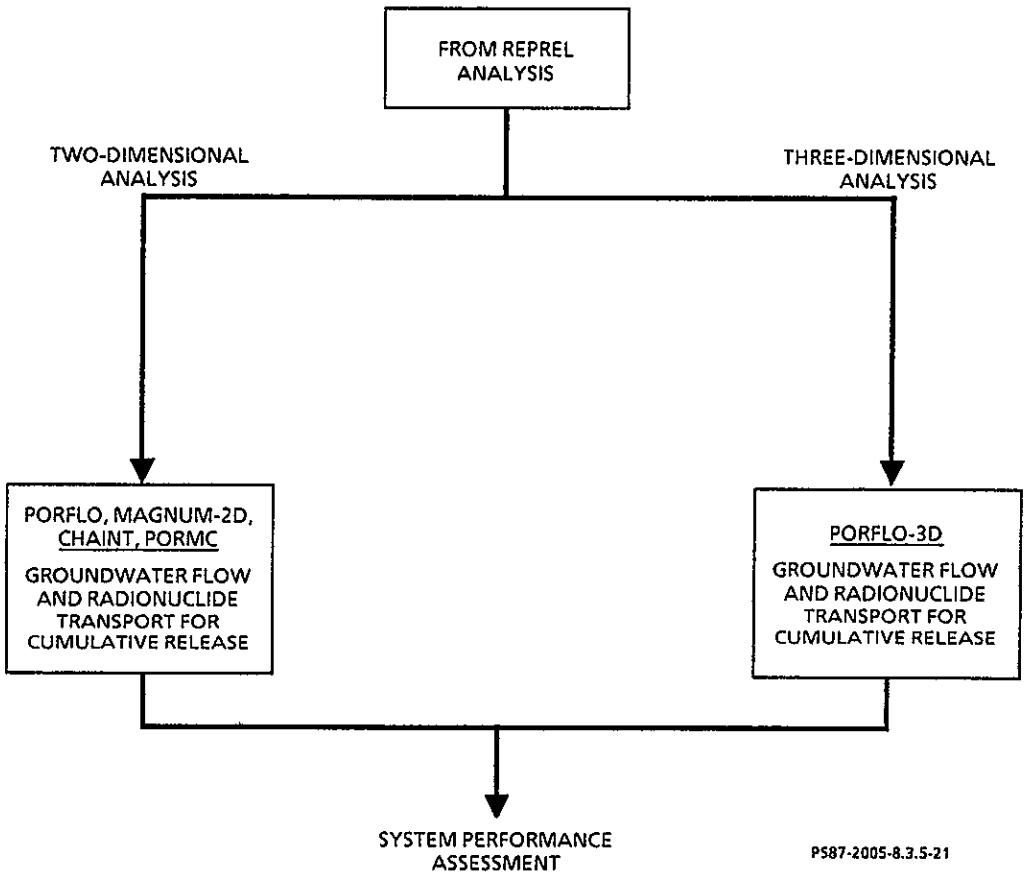

Figure 8.3.5-18. Codes for assessing repository seals subsystem performance. (See Sections 8.3.5.4 and 8.3.5.5 for descriptions of computer codes shown in this figure.)

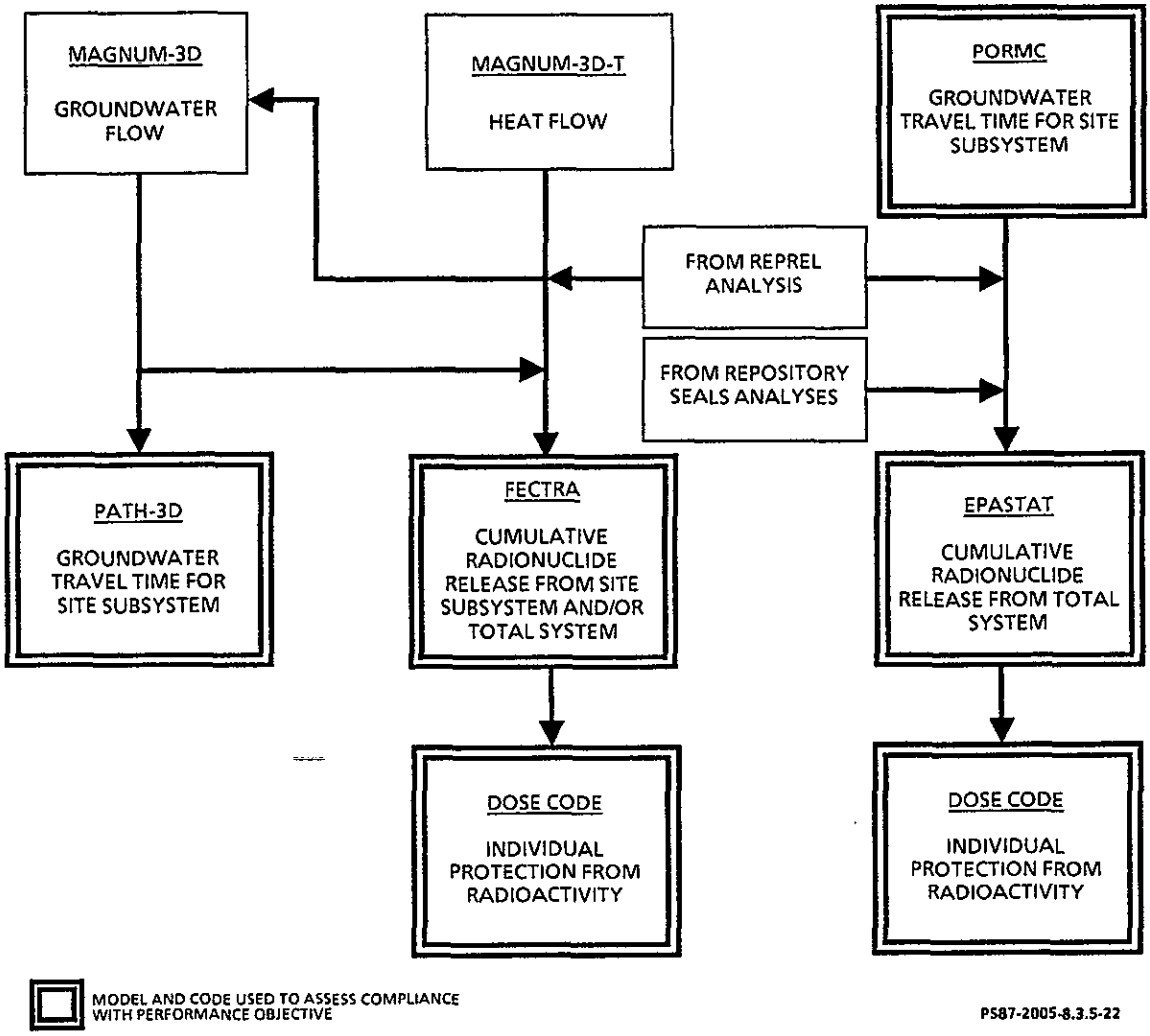

Figure 8.3.5-19. Codes for assessing the site subsystem and the overall repository system performance. (See Sections 8.3.5.4 and 8.3.5.5 for descriptions of codes shown in this figure.)

8.3.5.2.4.5 Assessing system performance

The assessment of system performance entails application of the system numerical models to determine the following:

- Performance of the system for undisturbed conditions (i.e., nominal-case distributions for all parameter values).
- Effects on system performance of changes induced by disruptive processes and events.
- Sensitivity of system performance to variation of the distributions of individual parameters.

Assessment of the performance of the overall repository system will begin by identifying important parameters and compiling data. A large part of the inputs for the system performance mathematical models will come from assessments of subsystem performance. For example, the radionuclide release rate source term to the system model will be provided by analyses of the engineered barriers and repository seals subsystem performances, and the groundwater velocities and travel times will come from an analysis of the site subsystem performance. Additional data will consist of radionuclide migration properties (e.g., porosity, dispersivity, adsorption), locations of model boundaries, and applicable scenarios.

Techniques of sensitivity analysis for the overall system will be similar to those discussed for the subsystems. For lumped-parameter system models (EPASTAT), it may be possible to analytically develop sensitivity coefficients because of the expressions used. Initially, this would be the preferred technique. Numerical techniques will be used to evaluate sensitivity for distributed-parameter models. For example, the sensitivity of performance to properties of the damaged rock zone or a postulated fault will be studied by numerical techniques. It is presently anticipated that probabilistic (Monte Carlo) models will be used in sensitivity analyses to determine the effects of perturbations in one or more input parameter distributions on output (performance measure) distributions. The plan for a sensitivity analysis in support of requirements definition for advanced conceptual design and site characterization is documented in Bridwell and Mease (1987).

The model used for probabilistic analysis of the system is EPASTAT (Eslinger and Sagar, 1986). A summary description of EPASTAT is provided in Section 8.3.5.4.

The results of cumulative release will include all scenarios having a probability of occurrence in 10,000 yr greater than 10^{-4}. The combined results of all scenarios including the nominal case will be assembled and displayed in the form of a complementary cumulative distribution function. This function provides a simple graphic display of the probability that the release into the accessible environment in 10,000 yr after repository closure will exceed any specific value. If the EPA allowable limits (EPA, 1986) are superimposed on the graph, compliance or noncompliance with the EPA standard is readily apparent (Section 8.2.2.1.1.3.5).

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8.3.5.2.4.6 Guiding additional work

If, based on preliminary assessments, a subsystem does not comply with its performance objectives but has been judged to be capable of compliance with either redesign, refinement of the performance assessment, or additional data, alternative courses of action that may lead to an acceptable system will be defined. The optimum course of action depends on the following:

- Nature and magnitude of the deficiency in demonstrating compliance with the performance objective.
- Ability of subsystems to compensate for other subsystem shortcomings.
- Cost and likelihood of success for alternative test programs aimed at acquisition of supplemental data.

Clearly, a determination based on performance assessment cannot, by itself, always determine which available option offers the most effective way and greatest probability of achieving an acceptable system. Nevertheless, the performance assessment tasks that guide additional work support the process leading to resolution of performance issues. By focusing the project on identifying those deficiencies specifically leading to a conclusion that the required subsystem performance at the requisite level of confidence has not been achieved, possibilities for corrective action (see Fig. 8.3.5-15) can be identified, and informed decisions can be made and justified. Such possibilities include the following:

- Refining models to include barrier effects previously held in reserve.
- Redesigning engineered elements of the system to improve performance.
- Performing additional tests to reduce uncertainties in key parameters.

8.3.5.2.4.7 Schedule and plans for assessing system performance

The scope of planned work for conducting system performance assessments includes implementing the disruptive scenario methodology, improving and documenting the systems model, and applying the systems model. The scope of planned work will be discussed in terms of the following:

- Integrating conceptual models.
- Defining scenarios.
- Developing a numerical systems model.
- Assessing system performance.

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8.3.5.2.4.7.1 Integrating conceptual models.

The conceptual model of the system reflects the conceptual model of the three subsystems (engineered barriers, repository seals, and site). As the conceptual models of these subsystems are enhanced, the conceptual model of the system will be reviewed and upgraded if necessary. The development and refinement of the system conceptual model will continue throughout the site characterization and design process.

8.3.5.2.4.7.2 Defining scenarios.

The methodology for identification and analyses of disruptive scenarios will be implemented during FY 1987 and 1988. Based on preliminary analyses of the disruptive scenarios, the adequacy of the existing systems model will be evaluated. The systems model may need to be modified to be able to address disruptive scenarios. The plan for a sensitivity analysis in support of identifying scenario classes that warrant detailed characterization is documented in Eslinger (1987).

8.3.5.2.4.7.3 Developing a numerical systems model.

The plans to develop a systems model that can be used to assess doses to the public resulting from the release of radionuclides to the accessible environment. Additional changes to the systems model will be defined in the future.

8.3.5.2.4.7.4 Assessing system performance.

An analysis of the cumulative release of radionuclides to the accessible environment for the site characterization plan conceptual design will be performed during FY 1987. A plan for analyses in support of the advanced conceptual design and license application design will be prepared as a result of this analysis and the preliminary analyses on disruptive scenarios. Sensitivity analyses will be used to identify key parameters at the system level (e.g., the effect of the damaged rock zone on the overall performance of the system).

8.3.5.3 Plans for demonstrating compliance with regulatory standards and siting guidelines

This section describes the activities needed to ensure that sufficient information is obtained to demonstrate the resolution of all issues and thereby to demonstrate compliance with applicable regulations.

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8.3.5.3.1 Demonstrating compliance with preclosure regulations

The process for preclosure safety assessments (see Section 8.3.5.1) will be implemented to ensure consideration of the preclosure regulations and guidelines embodied in Key Issue 2 on radiological safety during the operational phase. The activities for demonstrating compliance with preclosure regulatory requirements are listed in Table 8.3.5-3, and the table references the appropriate sections of the text.

The preclosure safety assessment process will be used to provide adequate confidence that during the preclosure period the repository will not pose any undue radiological risk to the health and safety of members of the public and repository operators as a result of possible credible accidents. The preclosure activities reviewed for accidents are repository operations, simultaneous mining, construction, emplacement, retrieval, decommissioning, and closure. Preclosure regulations are considered to apply only to projected radiological exposures resulting from credible accidents. Normal or operational exposures of the public and workers will be addressed under repository design considerations (see Section 6.4.4.4.2). There is no specific regulatory constraint on radiological exposure that is directly applicable to repository workers under accident conditions.

8.3.5.3.2 Demonstrating compliance with postclosure regulations

The process for postclosure performance assessments (see Section 8.3.5.2) will be implemented to ensure consideration of postclosure performance objectives related to Key Issue 1 on postclosure waste isolation. The activities for demonstrating compliance with postclosure regulatory requirements are listed in Table 8.3.5-4, and the table references the appropriate sections of the text. Specific strategies related to individual performance objectives are documented in Section 8.2.2.

8.3.5.3.3 Performance confirmation

The performance confirmation program conducted to resolve Issue 1.7 is designed to confirm, to the extent possible, that conditions and performance during repository construction and operation are within the ranges predicted in the license application. The performance objectives, derived from 10 CFR 60.137 (NRC, 1987a), cover radiological safety, retrievability during the construction and operation period, and the performance of the natural and engineered barriers after closure.

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Table 8.3.5-3. Documentation of the means for demonstrating compliance with preclosure regulations (sheet 1 of 2)

Reference	Regulation	Preclosure requirement	Performance assessment compliance methodology
EPA (1986)	40 CFR 191 Subpart A	Combined annual dose equivalent to any member of the public due to operations shall not exceed 25 mrem	Radiological assessments will be performed in the consequence analyses (see Section 8.3.5.1.5)
NRC (1987a)	10 CFR 60.111(a)	Protection against radiation exposure and releases of radioactive material	Radiological assessments will be performed in the consequence analyses (see Sections 8.3.5.1.4 and 8.3.5.1.5)
NRC (1987a)	10 CFR 60.111(b)	Retrievability of waste	Radiological and nonradiological assessments will be performed for disruption of repository (see Sections 8.3.5.1.4 and 8.3.5.1.5)
NRC (1987a)	10 CFR 60.131(a)	General design criteria for geologic repository operations area radiological protection	Radiological assessments will be performed in the consequence analyses (see Sections 8.3.5.1.4 and 8.3.5.1.5)
NRC (1987a)	10 CFR 60.131(b)	General design criteria for geologic repository operations area structures, systems, and components important to safety	The preclosure safety analysis will require accurate modeling of the design details of the systems involved (see Section 8.3.5.1.4)
NRC (1987a)	10 CFR 60.132	Additional design criteria for repository surface facilities	The preclosure safety analysis will require accurate modeling of the design details of the systems involved (see Section 8.3.5.1.4, Step 3)
NRC (1987a)	10 CFR 60.133	Additional design criteria for the repository underground facility	The preclosure safety analysis will require accurate modeling of the design details of the systems involved (see Section 8.3.5.1.4, Step 3)
NRC (1987a)	10 CFR 60.135	Criteria for the design of the waste package and its components	The preclosure safety analysis will require accurate modeling of the design details of the systems involved (see Section 8.3.5.1.4, Step 3)
NRC (1987b)	10 CFR 20	Limits on radiation exposure and concentration of radioactive material in restricted and unrestricted areas	Radiological assessments will be performed in the consequence analyses (see Section 8.3.5.1.4)
DOE (1987a)	10 CFR 960.5-1(a) (1) and (2)	Release of radioactive material to restricted and unrestricted areas during repository operation	Radiological assessments will be performed in the consequence analyses (see Section 8.3.5.1.4)
DOE (1987a)	10 CFR 960.5-2-1	Average radiation dose to members of the public within any highly populated area	Radiological assessments will be performed in the consequence analyses (see Section 8.3.5.1.4)
DOE (1987a)	10 CFR 960.5-2-2	Surface and subsurface activities during repository operation will not be likely to lead to radionuclide releases to an unrestricted area	Radiological assessments will be performed in the consequence analyses (see Section 8.3.5.1.4)
DOE (1987a)	10 CFR 960.5-2-3	Meteorologic conditions during repository operations will not likely lead to radionuclide release to unrestricted area	Consequence assessment will account for site meteorology (see Section 8.3.5.1.4, Step 9)

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Table 8.3.5-3. Documentation of the means for demonstrating compliance with preclosure regulations (sheet 2 of 2)

Reference	Regulation	Preclosure requirement	Performance assessment compliance methodology
DOE (1987a)	10 CFR 960.5-2-4	Nearby industrial, transportation, and military installations will not significantly affect repository operations and lead to radionuclide releases to an unrestricted area	Radiological assessments will be performed in the consequence analyses (see Section 8.3.5.1.4, Step 3)
DOE (1987a)	10 CFR 960.5-2-9	Characteristics and composition of the host rock will be suitable for accommodation of repository operation and will not cause undue hazard to personnel	System descriptions will consist of flow diagrams of unit operations that consider nonradiological personnel safety (see Section 8.3.5.1.4, Step 3)
DOE (1986b)	Order 5480.1B	Radiation protection standards for external and internal exposure from DOE operations	Radiological assessments will be performed in the consequence analyses (see Section 8.3.5.1.4)

NOTE: CFR = Code of Federal Regulations.
DOE = U.S. Department of Energy.
EPA = U.S. Environmental Protection Agency.
NRC = U.S. Nuclear Regulatory Commission.

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Table 8.3.5-4. Documentation of the means for demonstrating compliance with postclosure regulations

Reference	Regulation	Performance measure	Performance assessment compliance methodology
EPA (1986)	40 CFR 191.13, Subpart B	Limit on cumulative radionuclide mass flux to the accessible environment	Sections 8.2.2.1.1 and 8.3.5.2.4
EPA (1986)	40 CFR 191.15, Subpart B	Individual dose limits	Sections 8.2.2.1.2 and 8.3.5.2.4
EPA (1986)	40 CFR 191.16, Subpart B	Groundwater protection concentration and dose limits	Sections 8.2.2.1.3 and 8.3.5.2.4
NRC (1987a)	10 CFR 60.113	Radionuclide release limits for engineered barriers subsystem	Sections 8.2.2.1.5 and 8.3.5.2.1
NRC (1987a)	10 CFR 60.113	Minimum waste package containment time	Sections 8.2.2.1.4 and 8.3.5.2.1
NRC (1987a)	10 CFR 60.113	Minimum pre-waste-emplacement groundwater travel time	Sections 8.2.2.1.6 and 8.3.5.2.3

CFR = Code of Federal Regulations.
EPA = U.S. Environmental Protection Agency.
NRC = U.S. Nuclear Regulatory Commission.

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The program is divided into two major phases, the baseline phase and the confirmation phase, with license application being the dividing line between phases. Prior to license application, baseline data on conditions, predicted changes in those conditions as a result of construction and operation, and performance predictions are developed based on site characterization and testing. The performance confirmation phase begins with the license application review period and extends through the construction and operation period.

The preclosure performance confirmation program consists of tests and measurements designed to confirm predictions formulated during site characterization. Preclosure performance confirmation testing and analysis will also confirm that retrievability can be accomplished, ensure radiological safety, and provide information on the performance of seals and barriers systems. Test programs may be conducted during the construction and operation phases to substantiate predictions of postclosure performance.

Issue resolution during site characterization is an iterative loop of testing and analysis. The baseline data phase of the performance confirmation program will provide data to support resolution of Issues 1.1 through 1.6. Resolution of these issues, along with the definition of a performance confirmation program to confirm the performance assessments generated during the site characterization program, will be the basis of license application. The performance confirmation plan defines testing and monitoring studies aimed at confirming the predictions in the license application as well as plans for model validation not completed during site characterization.

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8.3.5.3.4 Model validation

The concept of classical validation, as defined by the International Atomic Energy Agency, is as follows:

> A conceptual model and the computer code derived from it are "validated" when it is confirmed that the conceptual model and the derived computer code provide a good representation of the actual processes occurring in the real system. Validation is thus carried out by comparison of calculations with field observations and experimental measurements.

Under this concept, the estimate of performance resulting from analysis would be compared to experimental measures of system performance. The classical process of validation for nuclear waste repository performance assessment modeling is precluded by the time scales over which the repository must continue to isolate waste (10,000 to 100,000 yr); i.e., direct experimental corroboration of models via full-scale, full-duration testing is impossible. In addition, the performance of the waste disposal system must be eliminated for a variety of potential future scenarios, even though only a single scenario will evolve at any given site. Sequential experiments at a given site for a variety of induced environmental conditions are unlikely to

approximate all of the potential scenarios. As a result of these considerations, an acceptable concept of "partial validation" must be defined.

To perform partial validation, numerical data obtained from scientific investigations will be used to ensure that descriptions and assumptions are appropriate and adequate. Additionally, peer review will assess the validation experiments and judge the uses made of results. However, the application of the results of scientific investigations imposes some of the same fundamental difficulties on partial validation as occurred in classical validation. For example, in a hydrogeologic system in which groundwater flow velocity is small (less than 1 mm/yr (0.04 in./yr)), direct measurement of mechanical dispersivity on the scale of 1 to 10 km (0.62-6.2 mi) will likely not be possible because a field experiment would have to run for thousands of years to yield pertinent data.

Clearly, only a subset of the activities needed for classical validation is achievable given the time and other constraints under which the DOE must perform its mission. Factors preventing full pursuit of partial validation include the following:

- The time allowed to reach conclusions on the validity of performance assessment models is limited. The continuing buildup of nuclear waste may require initiation of disposal before partial model validation (as described previously) can be achieved. A prescribed schedule exists for achieving operating nuclear waste repositories. However, it is believed that a sufficient amount of validation can be achieved to provide reasonable assurance of safety in the timeframe permitted.

- The financial resources available to pursue validation activities are limited. Some of the scientific investigations needed to address performance model validation are very expensive in terms of equipment, facilities, and personnel.

- The advisability of conducting field studies, in situ tests, and field experiments at the repository site is limited by the potential adverse effect that investigations might have on the integrity of the site and its ability to isolate waste. Consideration of this limitation is a regulatory requirement.

These limitations in time and resources require that the DOE define an acceptable subset of activities to achieve partial validation. These activities would be directed to resolving the following three questions.

1. Are the repository system and its important subsystems described accurately enough in terms of geometry and physical parameters?

2. For the repository and its important subsystems, are the internal operation conditions (e.g., temperature, pressure) and external states of nature adequately defined?

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3. For the repository and its important subsystems, are the physicochemical processes that are important in determining system performance identified?

The scientific investigations and activities that can be carried out on a human time scale to support resolution of these three questions are as follows:

- Peer review.
- Various scientific investigations (including laboratory experiments and field investigations such as in situ tests, field tests, and field studies).
- Natural analog studies.
- Theoretical scoping calculations.

These activities, separately or in combination, cannot achieve classical validation. However, they can, in combination, deliver a partial validation and can provide confidence that the models used in performance assessments are applicable to the system being represented.

8.3.5.3.4.1 Prioritizing validation activities

The following three criteria are used to organize and prioritize partial validation activities.

1. The priority given to the validation of a model is proportional to the role the model has in ensuring safe operation. This is equivalent to the priority the model has in demonstrating compliance with the EPA system requirement and the NRC subsystem requirements.
2. Priority should be given to validating models for which validation activities will significantly reduce uncertainties and demonstrate regulatory compliance with more confidence.
3. At a minimum, validation activities must be undertaken to provide reasonable assurance that the repository will perform within regulatory limits.

Selected types of investigations and activities that may provide useful information for validation (not including peer review) are listed in Table 8.3.5-5. Table 8.3.5-5 also provides definitions and synopses of the positive aspects and limitations of each type of activity listed.

Additionally, the results of many classical experiments are reported in the literature; it is possible that some of the reported results could be used in validation. Judicious use of experimental data available from the literature could reduce the need to perform some types of experiments. If used properly, some literature data can help to build confidence in performance assessment models, Such confidence building is an intergral part of the activities that contribute to achievable validation.

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Table 8.3.5-5. Definitions, favorable attributes, and unfavorable attributes of scientific investigation and analysis categories

Investigation and analysis category	Definition	Favorable attributes	Unfavorable attributes
Laboratory experiments	Experiments in a laboratory controlled environment on engineered material samples or samples from the field or artificially constructed analogs of field samples.	System properties and boundary conditions can be controlled; at small space and time scales, precise data on processes are possible. Repeatability may allow some quantification of uncertainties or varying of conditions may yield applicability information.	The problem of scaling laboratory test results to repository-scale space and time applications is very difficult and may prove intractable for many processes important to repository system or subsystem modeling.
In situ tests	Field experiments performed at depth. May involve components of the engineered barriers or the seals systems within the natural system.	Some control over degrees of freedom. Spatial scales may be on the order of some repository component scales. Repository environment may be approximated. Limited repeatability and ability to impose various stress conditions.	Control over degrees of freedom may be insufficient for some experiments. Time-scale difficulties may be as intractable as for laboratory experiments. Significant disruptions of the aspects of certain natural systems are unavoidable.
Field experiments	Experiments stressing the natural system hydraulically, mechanically, thermally, chemically, or by radiation. Induced changes are monitored to discover the response characteristics of the natural system.	Some control over degrees of freedom may be possible. Spatial scales at the same spatial magnitude as the waste package may be approximated. Field heterogeneity and parameter spatial variability may be estimated.	Inability to control all important system characteristics. Degrees of freedom may become an important limitation on scale and complexity of experiments. Repeatability is limited.
Field studies	Studies in which no additional stress is placed on the natural system but its behavior is monitored to determine its characteristics.	The natural system is minimally disturbed by test procedures. There is some control over degrees of freedom if system is not complex and (or) the spatial scale is not large. Heterogeneity of the system and spatial variability of important parameters may be approximated.	Uses system as is. Without induced stress, no response behavior is revealed; there is no repeatability for non-steady-state hydrologic systems. Time-scale problems are the same as for in situ and laboratory tests. Spatial-scale problems seriously impede some types of studies.
Natural analog studies	Studies of physical, chemical, geological, or archaeological phenomena issues or items that are similar in some respect to specific phenomena of the repository and (or) its subsystems.	Analogs may have a dynamic history or environment similar to that expected for the repository subsystem. Natural analogs would have developed over longer times than attainable in field or laboratory.	No precise knowledge about initial conditions, historical configurations, and hydrologic and other conditions that have prevailed until the present. Analogs may be as difficult as a repository to model and characterize.
Scoping analyses	Performance assessment analyses based on conservative estimates or bounding conditions and parametric values designed to give conservative or upper-limit estimates of containment or release consequences.	Useful exercise for determining relative importance of processes or subsystems to system performance, for allocating performance goals to subsystems or components, and for allocating resources.	Scoping calculations are only as credible as the models and data used. If the model used is inappropriate, results could be misleading and result in wasted resources.

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8.3.5.3.4.2 Objectives of achievable validation

Partial validation of performance assessment models is a key to providing reasonable assurance that performance projections support the granting of a license to construct, operate, and close a repository. The NRC has suggested that providing reasonable assurance consists of the following:

- Indicating in the DOE performance assessment that the likelihood of exceeding releases allowed by the EPA standard (EPA, 1986) is low.
- Satisfying the NRC that the performance assessment was sufficiently conservative and its limitations were sufficiently well understood to ensure that actual repository performance will be within the predicted limits.

Part of providing reasonable assurance involves ensuring that modeling approaches are justified and properly applied. Partial validation will provide this assurance through peer review and limited experimental work, which will provide confidence in the appropriateness of models and their applications.

8.3.5.3.4.3 Closure on validation

For the DOE to construct, operate, and close a repository, it is necessary to be licensed by the NRC. The license application safety analysis report will be evaluated by the NRC staff, and this evaluation will be reviewed through a hearing process that will probably be conducted by the Atomic Safety and Licensing Board. The hearing process is open to the public and has provision for entering concerns, issues, and contentions by the states, affected Indian tribes, and other interested parties in the scientific community and the general public.

Given the nature of the problem, it is assumed that the determination of sufficiency for model validation will be accomplished by peer review. The information supporting model validation will be reviewed with full consideration given to the implications of the model for regulatory compliance.

It is expected that the DOE peer reviewers will develop criteria before starting the reviews. The criteria are expected to be tied to (1) whether the validation activities are sufficiently complete and (2) whether the degree of validation ensures a certain level of performance. One approach to determining the second set of criteria would be to perform a series of subsidiary calculations to try to quantify the remaining uncertainties in performance due to modeling uncertainties that result from partial validation. If the criterion are met, the model will be considered validated. Validation activities could continue during the performance confirmation period.

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8.3.5.3.4.4 Summary

Specific validation plans must be formulated for each model essential to licensing. Performance assessment and other study plans will contain the detail of what is to be done, how it is planned to be done, and when it is to be done.

In terms of achieving a degree of validation, a number of types of scientific investigations were identified that may be supportive of validation. These include laboratory experiments, in situ tests, field experiments, field studies, natural analog studies, and scoping and sensitivity analyses.

Peer review is important in model validation activities and in determining closure or agreement on the sufficiency of the validation efforts.

8.3.5.4 Substantially developed analytic techniques

This section lists the mathematical models and computer codes that are considered substantially developed for preclosure safety and postclosure performance assessment and that are currently slated to be used in license application. Also described are methods for quantifying expert judgment in an auditable manner. Mathematical models and computer codes for which substantially more development is planned are given in Section 8.3.5.5.

Substantially developed analytical techniques are defined as those computer codes that have been used in support of past analyses. In particular, this list includes those computer codes that were used in support of preparing the Hanford Site Environmental Assessment (DOE, 1986a). These computer codes include CHAINT, MAGNUM-2D, PATH-2D, PORFLO, CHAINT-ML, EPASTAT, and REPREL. Other computer codes that are considered substantially developed but were not used in support of this analysis include QADMOD-G, SINDA, TSAP, TWODANT, ABAQUS, EQ3/6, KENO, MORSE-SGC/S, GEOTHER, and PORMC-SF. These codes, although not used in support of this analysis, are considered substantially developed because of their general acceptance by the technical community.

The procedures for development of performance assessment mathematical models and computer codes will conform with software management plan currently being prepared. In accordance with NRC requirements (Silling, 1982), the software management plan establishes categories of software and sets requirements for computer code documentation, testing (benchmarking, verification, and validation), and change controls for each category.

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This section is divided into three parts:

1. Deterministic modeling techniques (Section 8.3.5.4.1).

2. Probabilistic modeling techniques (Section 8.3.5.4.2).

3. Methods for quantifying and documenting expert judgment (Section 8.3.5.4.3).

Use of the deterministic and probabilistic analytic techniques to model predicted subsystem performance is described in terms of subsystem application, processes modeled, current quality of required input information, and principal reference(s). Each listing in the tables summarizing the deterministic and probabilistic modeling techniques is described in greater detail in the cited references. The use of substantially developed techniques for the elicitation and use of expert judgment in development and application of mathematical models is described.

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8.3.5.4.1 Deterministic codes

Deterministic mathematical models and computer codes are listed in Table 8.3.5-6. Mathematical models and computer codes that can use input parameters expressed probabilistically (i.e., as probability distribution functions) are listed in Section 8.3.5.4.2. Table listings and their annotated descriptions following the table are given alphabetically.

8.3.5.4.1.1 CHAINT

The CHAINT code simulates multicomponent radionuclide transport in fractured, porous media. The processes modeled include advection, dispersion, diffusion, sorption, chain decay, and mass release.

The computational method is based on a finite-element solution of the governing partial differential equation. Continuum portions of the media are modeled as a single-porosity system by using two-dimensional isoparametric elements. Radionuclide transport through discrete features, including matrix diffusion, are modeled using isoparametric line elements embedded along the sides of the two-dimensional elements.

The CHAINT code has the following major features:

- A generalized subroutine addressing combinations of radionuclides (actinides, fission, or activation products) with different half-lives.

- Subzone calculations in which the region of active nodes within the finite-element mesh is varied with time.

- Second-order accuracy and fully implicit.

Table 8.3.5-6. Substantially developed deterministic mathematical models and computer codes (sheet 1 of 3)

Model and code	Process(es) modeled	Subsystem application	Input parameters[a] from field and laboratory testing	Amount or source of data required[b] for input parameters and date required[c]			References and status[d]			
				5/88	6/89	2/94	Users manual	Technical report	Verification and bench-marking	Validation
CHAINT	Two-dimensional, multicomponent transport of chain-decay radionuclides in fractured, porous rock	Engineered barriers subsystem Repository seals subsystem Site subsystem	• Media densities • Effective porosities • Dispersivities • Radionuclide solubilities • Containment time • Fracture apertures • Radionuclide sorption coefficients • Molecular diffusion coefficients	3 2 3 3 3 3 2 3	3 1 3 2 2 3 1 2	2 1 2 1 1 3 1 1	Kline et al. (1985)	Planned issuance in 1988	Planned issuance in 1988	To be determined
MAGNUM-2D	Two-dimensional, coupled heat transport and transient groundwater flow in fractured, porous rock	Engineered barriers subsystem Repository seals subsystem Site subsystem	• Media densities • Effective porosities • Thermal conductivities • Specific heats • Dispersivities • Hydraulic conductivities • Specific storages	3 2 4 4 3 2 2	3 1 3 3 3 1 2	2 1 2 2 2 1 2	England et al. (1985)	Planned issuance in 1988	Eyler and Budden (1985)	To be determined
ONEDANT	Neutron and gamma ray transport	Engineered barriers subsystem	• Waste form and waste package geometry • Material types • Radiation source strength spectrum • Radiation source spatial distribution • Cross section data • Scattering and discrete coordinate angle expansion orders	1 5 5 5 5 5	1 5 5 5 5 5	1 4 4 4 5 5	O'Dell et al. (1982)	O'Dell et al. (1982)	To be determined	To be determined
PATH-2D	Two-dimensional groundwater flow paths and travel times	Engineered barriers subsystem Repository seals subsystem Site subsystem	• Output from MAGNUM-2D, including effective porosity and hydraulic conductivity • Output from PORFLO, including effective porosity and hydraulic conductivity	-- --	-- --	-- --	Planned issuance in 1988	Planned issuance in 1988	Planned issuance in 1989	Not applicable

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Table 8.3.5-6. Substantially developed deterministic mathematical models and computer codes (sheet 2 of 3)

Model and code	Process(es) modeled	Subsystem application	Input parameters[a] from field and laboratory testing	Amount or source of data required[b] for input parameters and date required[c]			References and status[d]			
				5/88	6/89	2/94	Users manual	Technical report	Verification and bench-marking	Validation
ABAQUS	Three-dimensional static and dynamic structural mechanics and heat conduction	Engineered barriers subsystem Site subsystem	• Structural properties • Densities • Applied loads or stress boundary conditions • Thermal conductivities	3 3 3 3	1 1 1 1	1 1 1 1	Hibbitt et al. (1985)	To be determined	To be determined	To be determined
PORFLO	Two-dimensional groundwater flow and heat and radionuclide transport	Engineered barriers subsystem Repository seals subsystem Site subsystem	• Media densities • Effective porosities • Thermal conductivities • Specific heats • Dispersivities • Hydraulic conductivities • Specific storages • Radionuclide solubilities • Containment time • Radionuclide release durations • Radionuclide sorption coefficients • Molecular diffusion coefficients	3 2 4 4 3 2 2 3 3 3 2 3	3 1 3 3 3 1 2 2 2 2 1 2	3 1 3 3 3 1 2 1 1 1 1 1	Kline et al. (1983)	Runchal et al. (1985)	Eyler and Budden (1984), Runchal et al. (1985)	Issuance of Plan in 1988
QADMOD-G	Radiation shielding analysis	Engineered barriers subsystem	• Mass attenuation coefficients • Media densities • Thermal conductivities • Specific heats • Waste form and waste package geometries	5 5 4 4 1	5 4 3 3 1	5 3 2 2 1	Price and Blattner (1979)	Price and Blattner (1979)	To be determined	To be determined
SINDA	Thermal analysis	Engineered barriers subsystem	• Media densities • Thermal conductivities • Specific heats • Convection	5 4 4 4	4 3 3 3	3 2 2 2	Smith (1971)	Smith (1971)	To be determined	To be determined
EQ3/6	Geochemical analysis	Engineered barriers subsystem	• Groundwater chemical composition • Mineral composition of rock • Waste form chemical composition	TBD	TBD	TBD	Wolery (1979)	Wolery (1979)	To be determined	To be determined

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Table 8.3.5-6. Substantially developed deterministic mathematical models and computer codes (sheet 3 of 3)

Model and code	Process(es) modeled	Subsystem application	Input parameters[a] from field and laboratory testing	Amount of source of data required[b] for input parameters and date required[c]			References and status[d]			
				5/88	6/89	2/94	Users manual	Technical report	Verification and bench-marking	Validation
TWODANT	Neutron and gamma ray transport	Engineered barriers subsystem	• Waste form and waste package geometry	1	1	1	Alcouffe et al. (1984)	O'Dell et al. (1982)	To be determined	To be determined
			• Material types	1	1	1				
			• Radiation source strength spectrum	5	5	4				
			• Radiation source spatial distribution	5	5	4				
			• Cross-section data	5	5	5				
			• Scattering and discrete coordinate angle expansion orders	5	5	5				
TSAP	Thermal analysis	Engineered barriers subsystem	• Media densities	5	4	3	Planned issuance in 1988	Planned issuance in 1988	Planned issuance in 1988	To be determined
			• Thermal conductivities	4	3	2				
			• Specific heats	4	3	2				
			• Convection	4	3	2				
SANGRE	Coupled two-dimensional deformation, heat flow, fluid flow, and faulting	Site subsystem	• Elastic properties	3	2	1	Anderson (1986)	Anderson (1986)	To be determined	To be determined
		Engineered barriers subsystem	• Creep properties	3	2	1				
			• Thermal properties	3	2	1				
			• Fluid properties	3	2	1				
		Repository seals subsystem	• Fault properties	3	2	1				

NOTE: Items designated by (--) are not applicable. PST87-2005-8.3.5-5

[a]Other input parameters are required (e.g., half-life, grid size, waste age, barrier thickness, and thermal output). However, such parameter values can be assigned independently of site-specific laboratory or field testing findings or other site-specific research.

[b]Quality of data is expressed in relative terms, with 1 being a higher quality than 5. Judgments of required data quality are subjective but are based on apparent sensitivity of model results to input parameter values.

5 = Data based on literature review with few, if any, site-specific measurements.
4 = Sufficient data to establish site-specificity of the expected value.
3 = Sufficient data to establish a range of site-specific values.
2 = Sufficient data to establish statistical inference of distribution of values.
1 = Sufficient data to establish a probability distribution or a single, representative value with high confidence.

[c]Date that a given quality of data for a specific parameter is required based on programmatic schedules for assessing performance with a given level of confidence derived from the allocated reliability goals. Schedule is subject to change.

[d]Reports on probabilistic and (or) three-dimensional variants of existing models and codes may be issued as updates of parent model and code reports. All dates are based on fiscal year beginning October 1.

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A user manual for CHAINT has been prepared (Kline et al., 1985). Preliminary verification and benchmark testing of CHAINT are being documented. A technical report will be issued in FY 1988.

8.3.5.4.1.2 MAGNUM-2D

MAGNUM-2D is a two-dimensional, finite-element computer code and mathematical model simulating transient groundwater flow and heat transport in fractured, porous rock.

A dual-porosity approach is used in which groundwater flow is treated as a combination of flow through planar conduits and flow in a porous rock matrix (Baca et al., 1987). The governing equations and finite-element solution techniques are given by Baca et al. (1981).

The principal features of MAGNUM-2D are as follows:

- Representation of the rock mass as a continuum by isoparametric finite elements.
- Line elements to represent discrete fractures that are embedded along the sides of two-dimensional elements.
- Stratigraphic features that include variable media properties.
- Coupled or uncoupled solutions of heat and flow equations.
- Flow-field calculations that provide input to flow path and radionuclide transport models.

A user manual for MAGNUM-2D has been prepared (England et al., 1985), and preliminary verification and benchmark testing have been completed (Eyler and Budden, 1985). A technical report will be issued in FY 1988.

8.3.5.4.1.3 ONEDANT

The ONEDANT code is a multigroup discrete-ordinates radiation transport code that solves the Boltzmann equation for neutron or gamma rays or both simultaneously. When solving gamma-ray transport only, it functions as a radiation shielding code. When neutrons are included, it can be used as a criticality code.

The code solves problems in spherical geometry as well as in one-dimensional cylindrical and plane geometry. The ONEDANT code will be used for scoping analyses and preliminary analyses for the two-dimensional version, TWODANT.

A user manual and technical report is available (O'Dell et al., 1982) for the ONEDANT code. Dates for documentation of verification and benchmark testing and for issuing plans for model validation have not yet been established.

8.3.5.4.1.4 PATH-2D

Using the numerical results from a two-dimensional groundwater model (MAGNUM-2D or PORFLO), the PATH-2D code computes the flow paths for an arbitrary set of starting points in the area of interest. In addition to computing the particle trajectories, PATH-2D computes the cumulative time of travel along each trajectory (i.e., groundwater travel time).

The PATH-2D code solves the flow-path equations on a finite-element grid network, thereby tracing the particle trajectory from element to element. This code is designed for interactive use on a standard graphics terminal. Major features of PATH-2D are as follows:

- Solution of the flow-path equation by a predictor-corrector algorithm and finite-element shape functions.
- Two-dimensional isoparametric elements with one-dimensional line elements.
- Graphic output with options for superimposing the finite-element mesh, rock type boundaries, and plots for subzone grids.

A user manual and technical report for PATH-2D will be prepared during FY 1988. Verification and benchmark testing of PATH-2D are also planned for FY 1989. The BWIP does not currently plan to validate PATH-2D (also see PATH-3D).

8.3.5.4.1.5 PORFLO

The PORFLO code is a two-dimensional, integrated, finite-difference computer code and mathematical model capable of simulating the coupled processes of groundwater flow, heat transfer, and radionuclide transport. PORFLO is applicable to a porous or highly jointed rock that can be represented as equivalent to a porous media.

The solution technique uses the method of nodal point integration, in conjunction with the alternating direction implicit technique, to generate and solve the finite-difference equations. An additional description of PORFLO is contained in Runchal et al. (1985). Major features of PORFLO are as follows:

- Inexpensive and easy to use.
- Can be applied to axially symetric systems as two-dimensional cross sections.
- Conservation of energy and mass at the grid-block level.
- Calculation of total activity (groundwater flow and radionuclide transport) crossing assigned boundaries during a specified period of time.

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A user manual for the PORFLO computer code and mathematical model has been prepared (Kline et al., 1983). A technical report has been issued and documentation of preliminary verification and benchmark testing of PORFLO has been completed (Eyler and Budden, 1984; Runchal et al., 1985). PORFLO was submitted to the NRC for testing. To date, results from their testing are not known to the BWIP. The BWIP will issue a plan for validation of PORFLO in FY 1988.

8.3.5.4.1.6 QADMOD-G

The QADMOD-G code is being considered for the BWIP radiation shielding analysis. This code will calculate the gamma-ray flux, dose rate, and heating rate both within and outside a gamma radiation source. The source region is divided into a number of small volumes within which the distributed sources are represented as point sources. The QADMOD-G code calculates the gamma-ray flux at a selected point by computing the attenuation along the line of sight between that point and each source point, accounting for secondary (scattered) gamma rays by buildup factors, and summing the results from all source points.

A combined user manual and technical report is available (Price and Blattner, 1979) for the QADMOD-G code. The code has not yet been installed on computers accessible to the BWIP modelers. Dates for installation and completion of documentation have not yet been established.

8.3.5.4.1.7 SINDA

SINDA is a software system (subroutine library) for thermal analysis. This system represents a thermal system as a network of lumped-parameter elements. The code contains a heat conduction equation for the link between each pair of network elements. This system of equations is expressed as a system of algebraic equations by the finite-difference formalism; the algebraic equations are then solved simultaneously.

The SINDA code can be used to model a wide range of physical phenomena, including melting and boundary conditions (e.g., boiling heat transfer). The code is capable of solving heat conduction problems accurately and efficiently in complicated geometrical configurations.

A user manual for the SINDA code is available (Smith, 1971). Dates for documentation of verification and benchmark testing and for issuing plans for model validation have not yet been established.

8.3.5.4.1.8 TSAP

The TSAP code is analogous to SINDA but is greatly simplified. The TSAP code is intended to be run on a desktop computer. It is suitable for making the numerous runs necessary for performance sensitivity investigations.

A user manual, including technical report and documentation of verification for the TSAP code, is scheduled to be issued in FY 1988. Dates for issuing the plans for model validation have not yet been established.

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8.3.5.4.1.9 TWODANT

The TWODANT code is a multigroup discrete-ordinates radiation transport code that solves the Boltzmann equation for neutron or gamma rays or both simultaneously. When solving gamma-ray transport only, it functions as a radiation shielding code. When neutrons are included, it can be used as a criticality code. This code is a two-dimensional version of ONEDANT and can solve two-dimensional problems in plane geometry, r-z cylindrical geometry, or r-theta cylindrical geometry.

A user manual and technical report is available for the TWODANT code (O'Dell et al., 1982). Dates for documentation of verification and benchmark testing and for issuing plans for model validation have not yet been established.

8.3.5.4.1.10 SANGRE

The SANGRE code simulates coupled deformation, transient Fourier heat conduction, transient Darcy flow, and faulting. The constitutive model is expressed in terms of elastic, creep, thermal, and fluid strain rates. The SANGRE code solves two-dimensional plane stress, plane strain, and axi-symmetric problems. The computational method is based on the finite element solution to the governing partial differential equations.

The SANGRE code has the following features:

- Elastic solutions.
- Nonlinear thermal creep.
- Transient heat conduction.
- Transient Darcy flow.
- Faulting with slide lines.

A users manual details theory, input, and selected geomechanical problems (Anderson, 1986).

8.3.5.4.1.11 ABAQUS

The ABAQUS code is a proprietary general-purpose finite element code for structural analysis, heat conduction analysis, and coupled structural and heat conduction analysis. It is capable of modeling viscoelastic and viscoplastic phenomena, and it can solve transient structural problems such as impact loading problems. The primary application of ABAQUS by the BWIP will be to model geomechanics phenomena and to perform waste package structural analysis.

The ABAQUS code is extensively documented by the vendor; in particular, a thorough user's guide is supplied to authorized users of the code (Hibbitt et al., 1985).

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8.3.5.4.1.12 EQ3/6

The EQ3/6 code package was developed by Lawrence Livermore National Laboratory to model geochemical phenomena involving groundwater interactions with minerals. The EQ3 code is a chemical equilibrium module that uses input characterizing the groundwater (e.g., the concentrations of all chemical elements in solution) to solve for the equilibrium concentrations of all chemical species present (i.e., compounds and radicals). Also, the EQ3 code computes the degree of saturation of the species in the solution, with respect to mineral phases, at the groundwater temperature. The EQ6 code analyzes the interaction of the groundwater composition (as determined by EQ3) with some source of chemical species such as the host rock or the waste form. The output of EQ6 includes prediction of the masses of rock and waste form dissolution and mineral precipitation.

The EQ3/6 code package is documented in Wolery (1979).

8.3.5.4.2 Probabilistic codes

The EPA (1986) requires that assessments of long-term repository performance incorporate uncertainties as a probability distribution of cumulative radionuclide releases. In response to this requirement, the BWIP has developed Monte Carlo and finite-order stochastic mathematical models and numerical computer codes that probabilistically simulate long-term geologic repository performance.

The mathematical models and computer codes listed in Table 8.3.5-7 are employed in computer simulations for which results are expressed as cumulative probability distribution functions. Table listings and the annotated descriptions that follow are given alphabetically.

8.3.5.4.2.1 CHAINT-MC

The CHAINT-MC computer code and mathematical model is a two-dimensional mass-transport model that calculates probability density functions for annual rates of radionuclide release and integrated radionuclide flux at or past a specific boundary. The CHAINT-MC code is a specialized version of the CHAINT deterministic computer code and mathematical model in which input variables are specified as probability distributions. A Monte Carlo sampling technique is used to select a set of input variables for analysis.

The BWIP currently plans to issue a user manual, technical report, and documentation of verification and benchmarking of CHAINT-MC in FY 1988. Plans for validation of the mathematical model have not yet been determined.

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Table 8.3.5-7. Substantially developed probabilistic mathematical models and computer codes (sheet 1 of 2)

Model and code	Process(es) modeled	Subsystem application	Input parameters[a] from field and laboratory testing	Amount or source of data required[b] for input parameters and date required[c]			References and status[d]			
				5/88	6/89	2/94	Users manual	Technical report	Verification and bench-marking	Validation
CHAINT-MC	Two-dimensional, multicomponent transport of chain-decay radionuclides in fractured, porous rock using probabilistically distributed variables	Engineered barriers subsystem, waste package component Repository seals subsystem Site subsystem	• Output from PCM-STAT	--	--	--	Planned issuance in 1987	Planned issuance in 1987	To be prepared in 1988	To be determined
EPASTAT	Cumulative radionuclide flux compared to the U.S. Environmental Protection Agency limit using distributed variables	Overall geologic repository system	• Output from REPREL • Output from PORMC • Dispersivities • Effective porosities	-- -- 3 2	-- -- 3 1	-- -- 2 1	Eslinger and Sagar (1986)	Eslinger and Sagar (1986)	Planned issuance in 1988	--
KENO	Neutron and gamma ray transport	Engineered barriers subsystem	• Waste form and waste package geometry • Material types • Radiation source strength spectrum • Radiation source spatial distribution • Cross-section data • Scattering and discrete coordinate angle expansion orders	1 1 5 5 5 5	1 1 5 5 5 5	1 1 4 4 5 5	Petrie and Landers (1981)	Petrie and Landers (1981)	To be determined	To be determined
PORMC-SF	Two-dimensional, steady-state groundwater flow	Site subsystem	• Effective porosities • Hydraulic conductivities	2 2	1 1	1 1	Planned issuance in 1989	Planned issuance in 1989	To be determined	--
REPREL	Fractional radionuclide release rates, accounting for distributed container failure rate	Waste package component Engineered barriers subsystem	• Output from CHAINT-MC	--	--	--	Eslinger and Sagar (1985)	Sagar et al. (1984)	To be determined	--

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Table 8.3.5-7. Substantially developed probabilistic mathematical models and computer codes (sheet 2 of 2)

Model and code	Process(es) modeled	Subsystem application	Input parameters[a] from field and laboratory testing	Amount or source of data required[b] for input parameters and date required[c]			References and status[d]			
				5/88	6/89	2/94	Users manual	Technical report	Verification and bench-marking	Validation
MORSE-SGC/S	Neutron and gamma ray transport	Engineered barriers subsystem	• Waste form and waste package geometry	3	2	1	Petrie and Landers (1981)	Petrie and Landers (1981)	To be determined	To be determined
			• Material types	3	2	1				
			• Radiation source strength spectrum	3	2	1				
			• Radiation source spatial distribution	3	2	1				
			• Cross-section data	3	2	1				
			• Scattering and discrete coordinate angle expansion orders	3	2	1				

NOTE: Items designated by (--) are not applicable.

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[a]Other input parameters are required (e.g., half-life, grid size, waste age, barrier thickness, and thermal output). However, such parameter values can be assigned independently of site-specific laboratory or field testing findings or other site-specific research.

[b]Quality of data is expressed in relative terms, with 1 being a higher quality than 5. Judgments of data quality required are subjective but are based on apparent sensitivity of model results to input parameter values.

5 = Data based on literature review with few, if any, site-specific measurements.
4 = Sufficient data to establish site-specificity of the expected value.
3 = Sufficient data to establish a range of site-specific values.
2 = Sufficient data to infer an approximate probability distribution or an approximate representative value.
1 = Sufficient data to establish a probability distribution or a single, representative value with high confidence.

[c]Date that a given quality of data for a specific parameter is required based on programmatic schedules for assessing performance with a given level of confidence derived from the allocated reliability goals. Schedule is subject to change.

[d]Reports on probabilistic and (or) three-dimensional variants of existing models and codes may be issued as updates of parent model and code reports. All dates are based on fiscal year beginning October 1.

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8.3.5.4.2.2 EPASTAT

The EPASTAT computer code is used to assess system performance in isolating radionuclides from the accessible environment. This code can be used to calculate the cumulative radionuclide flux at a specified distance from the edge of the repository and compare that flux with the limit specified by 40 CFR 191 (EPA, 1986).

EPASTAT models one-dimensional advective and diffusive transport through a saturated homogeneous medium. A time-dependent source term can be used and input data can be specified as probability distributions. The EPASTAT has been used extensively to evaluate the effects of parameter uncertainties on waste isolation performance conditions.

A technical report and user manual that provides details of the mathematical formulation for EPASTAT was released in FY 1986 (Eslinger and Sagar, 1986). The BWIP plans to do additional documentation and verification during FY 1988.

8.3.5.4.2.3 KENO

The KENO code (Petrie and Landers, 1981) is a Monte Carlo code developed at the Oak Ridge National Laboratory specifically as a criticality code. Its accuracy in computing neutron flux is not acceptable, but it is considerably faster in computing the neutron multiplication factor than the MORSE-SGC/S code. For this reason, the MORSE-SGC/S code (Section 8.3.5.4.2.4) is generally used for shielding purposes, and the KENO code is used for criticality calculations. Except for the distinction in application, the discussion of KENO is essentially the same as that for MORSE-SGC/S.

The KENO code has not yet been installed in computers accessible to the BWIP modelers. Dates for installation and documentation have not yet been established.

8.3.5.4.2.4 MORSE-SGC/S

The multigroup Monte Carlo code MORSE-SGC/S solves the integral transport equation statistically for neutrons or gamma rays or both simultaneously. The integral transport equation is discussed in Bell and Glasstone (1970), and Monte Carlo methods for radiation transport are discussed in Spanier and Gelbard (1969). The MORSE-SGC/S code is more commonly used as a radiation shielding code than a criticality code, although it can serve either purpose.

This code allows the construction of geometrical arrangements from a variety of basic forms. This feature is useful in waste package shielding analysis because the intact fuel assemblies are square in cross section, while the waste container is a right circular cylinder.

The MORSE-SGC/S code was developed at the Oak Ridge National Laboratory and is available for distribution. However, the code has not yet been installed in computers accessible to BWIP modelers. Dates for installation and documentation have not been established.

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8.3.5.4.2.5 PORMC-SF

PORMC-SF is a simplified version of PORMC. It solves the steady-state, two-dimensional groundwater flow equation. Specifically, PORMC-SF is designed to perform stochastic analyses of groundwater flow and groundwater travel times in a bounded domain. Uncertain inputs that can be considered by PORMC-SF are the permeability and effective porosity fields and boundary conditions. These inputs can be modeled as either univariate random variables or spatial stochastic processes. Groundwater travel times are analytically calculated by PORMC-SF following numerical solution of the groundwater flow equation. The user manual and technical report for PORMC-SF will be issued in FY 1989.

8.3.5.4.2.6 REPREL

REPREL calculates the annual rates of release of radionuclides from a repository in which the waste containers fail at different times. The container failures are described by a Poisson stochastic process. Parameters are estimated by an analysis of the failure of a single container.

Technical details and theory are given in Sagar et al. (1984). A user manual has been published (Eslinger and Sagar, 1985). A specific plan for testing of the code has not yet been defined.

8.3.5.4.3 Preclosure computer codes

Unlike the computer codes used for postclosure performance assessment, many of the computer codes used in preclosure safety assessment are adopted from codes used for other nuclear safety assessments (e.g., assessments of reactors).

Examples of computer codes suitable for use in assessing the preclosure safety of the basalt repository site are listed in Table 8.3.5-8. These computer codes fall into two broad categories: preclosure repository systems analyses and preclosure repository consequence analyses. Computer codes for preclosure repository systems analyses perform (1) initiating event identification and quantification (e.g., criticality, fire, seismic activity, and flood); (2) systems reliability studies such as fault tree analyses and failure modes and effects analyses; (3) human reliability analysis; (4) common-cause failure analysis; (5) accident sequence quantification; and (6) uncertainty, sensitivity, and importance analyses. Computer codes for preclosure repository consequence analyses include (1) source-term characterization, (2) in-repository consequence analysis, (3) environmental transport and off-site consequence analyses, (4) economic consequence analysis, and (5) uncertainty and sensitivity analyses. In addition to the computer codes listed in Table 8.3.5-8, some simple analytical techniques, such as hand calculations, may be used in preclosure safety assessment. The last column in Table 8.3.5-8 lists the issues in which these codes could be used. Table 8.3.5-9 gives a brief description of each code identified in Table 8.3.5-8 and the status of the computer code documentation.

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Table 8.3.5-8. Computer codes for use in preclosure safety assessment

Categories of preclosure safety assessment	Type of analysis	Examples of computer codes	Issue in which the code may be used[a]
Systems analyses	Criticality	KENO-IV	2.1, 2.2
	Systems reliability	SETS	2.3
	Shielding code	ANISN	2.1, 2.2, 2.3
Consequence analyses	Source-term characterization	ORIGEN-2	2.1, 2.2, 2.3
	Public exposures	GASDOSE	2.1
	Public exposures	AIRDOS-EPA	2.1, 2.2
	Public exposures	CRRIS system	2.1, 2.2, 2.3
	Public exposures	DACRIN	2.3

[a]Issues 2.1, 2.2, and 2.3 are discussed in Sections 8.2.2.2.1, 8.2.2.2.2, and 8.2.2.2.3, respectively.

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Table 8.3.5-9. Description of computer codes

Code	Code description	Status of documentation*
AIRDOS-EPA	Routine-release dose consequences (Clean Air Act of 1977 compliance)	User manual extant; no verification; some limited validation
ANISN	Discrete-ordinate for shielding	User manual extant; no verification and validation data
CRRIS System	New EPA-funded radioactive-release dose consequences	Documentation in preparation; limited verification and validation
DACRIN	Accident-release, airborne-pathway dose consequences	User manual extant; limited validation only
GASDOSE	See AIRDOS-EPA	Proprietary
KENO-IV	Monte Carlo criticality and shielding	User manual extant; has been validated
ORIGEN-2	Radionuclide inventory of spent fuel	User manual extant; verification and validation underway
SETS	Fault tree and event tree analysis	User manual extant; no verification and validation data

NOTE: These codes are identified in Table 8.3.5-7.
*The computer code documentation has not been reviewed.

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The Preclosure Risk Assessment Methodology (PRAM) program is assessing the computer codes to determine the most appropriate computer codes to be used uniformly by all the repository projects.

8.3.5.4.4 Use of expert judgment

Extensive application and documentation of expert subjective judgment is required in the following aspects of performance assessment for a high-level nuclear waste repository:

- Provide information on difficult-to-measure model parameters.
- Determine probability of occurrence of disruptive scenarios.
- Validate mathematical models and computer codes.
- Review modeling results.
- Evaluate quality and applicability of experimental data for use in models.

Peer reviews related to each of these aspects of performance assessment will be conducted in accordance with formal procedures that reflect decision-making techniques generally accepted by the technical community.

Probability encoding is a process used to quantify expert judgment concerning uncertainties that bear on a decision as probability distributions. A probability encoding technique has been used by the BWIP to obtain information, in advance of site characterization, on site-specific values of effective porosity, hydraulic conductivity, and anisotropy of basalt (Runchal et al., 1984a, 1984b). This technique will be used in the future to obtain subjective data on parameters that are difficult to measure or for which field data will not be available at the time they are needed.

The Delphi technique (Helmer, 1966; Dalkey, 1972) is a systematic and auditable approach to obtaining expert opinion on complex issues. The method consists of the selection of a panel of persons expert on the matter in question and the iterative administration of a questionnaire to each panel member. Measures of central tendency and dispersion are applied to the final results to express the consensus of the panel of experts. The Delphi technique has been used by the BWIP to formulate a list of generic disruptive scenarios and then to rank them in terms of their importance to the waste isolation capability of the Hanford Site (Davis et al., 1983). The Delphi technique will be used to assign probabilities of occurrence to postulated disruptive scenarios.

Computer codes and models are developed by a multistep process to build confidence in the models required to determine compliance with regulatory criteria. A user manual and a technical report describing the mathematical

model and its implementation are issued to provide a basis for review of the mathematical formulation of the system and its solution algorithm. Another step is the performance of verification and benchmarking tests to check the accuracy of the numerical solution against the mathematical model and against similar codes. The final confidence-building step, model validation, is accomplished principally by comparing model predictions to the results of laboratory and field tests and natural analogs and is also done in part by using expert judgment. This latter aspect of validation (i.e., expert judgment) is accomplished by providing the experimental data and model development information to one or more experts and then obtaining their judgment as to whether the mathematical model presented and the numerical solution, as embodied in the computer code, are valid for determining compliance with regulatory criteria.

When a model has been validated (provided the model has been applied correctly and its outputs are correctly interpreted), it is considered able to adequately predict long-term isolation of the radioactive waste from the environment. Acceptable modeling results are obtained by using site-representative data in a validated model. Modeling results used in performance assessment will be reviewed by experts to determine if (1) the data used are representative of the site and (2) the results are correctly interpreted.

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8.3.5.5 Analytic techniques requiring significant development

This section lists the postclosure performance assessment mathematical models and computer codes that require significant additional development by the BWIP and are slated to be used in license application. Also described is the framework within which the BWIP will use expert judgment to determine priorities of information needed to adequately assess repository performance.

This section is divided into three parts:

1. Deterministic modeling techniques (Section 8.3.5.5.1).
2. Probabilistic modeling techniques (Section 8.3.5.5.2).
3. The framework for eliciting and using expert opinion (Section 8.3.5.5.3).

The deterministic and probabilistic analytic techniques are described in terms of (1) subsystem application, (2) processes modeled, (3) current quality of required input information, and (4) principal reference(s). Each listing in the tables summarizing the deterministic and probabilistic modeling techniques is described in greater detail in the cited references.

As implied, analytical techniques requiring significant development are defined as the set of computer codes that have not been used routinely to

support analyses. These codes are at various stages of development. For example, the MAGNUM-3D computer code is considered essentially complete and will be available to support analysis in the near future. On the other hand, the SPAM computer code is in the early stages of development. For the SPAM computer code specific requirements are presently being defined; this is essentially the initial step in the development process.

At this time, no preclosure computer codes have been identified that require significant development. It is expected that standard industry computer codes will be used for preclosure safety assessment.

8.3.5.5.1 Deterministic codes

The mathematical models and computer codes listed in Table 8.3.5-10 will be employed in computer simulations that require discrete values for input parameters. Mathematical models and computer codes that will use input parameters expressed probabilistically (i.e., as cumulative probability distribution functions) are listed in Section 8.3.5.5.2. Table listings and their annotated descriptions following the table are given alphabetically.

8.3.5.5.1.1 FECTRA

The FECTRA code, when completed, will simulate two- or three-dimensional transport of radionuclides in porous media. This code will solve the transport equation rather than the groundwater flow equation.

The features incorporated by this computer code and mathematical model will include advection, dispersion, diffusion, sorption, decay, and release of multiple radionuclide species. The FECTRA code is designed to be fully compatible with MAGNUM-3D. Inputs include the hydraulic head field from the MAGNUM-3D groundwater flow simulator, definition of geometry (same input as for MAGNUM-3D), and definition of material property. Chain decay of radionuclides, with daughter products being produced from the initial waste inventory, is not currently included in FECTRA (see description of CHAINT in Section 8.3.5.4).

The key features of FECTRA are as follows:

- Three-dimensional, steady-state, or transient simulation of solute (radionuclide) transport.
- Finite-element, Galerkin method using isoparametric elements with quadratic basis functions.
- Chemical sorption and decay addressed.
- Simultaneous transport of more than one solute species.
- Heterogeneous and anisotropic media.

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Table 8.3.5-10. Deterministic mathematical models and computer codes requiring significant development (sheet 1 of 2)

Model and code	Process(es) to be modeled	Subsystem application	Input parameters[a] from field and laboratory testing	Amount or source of data required[b] for input parameters and date required[c]			References and status[d]			
				5/88	6/89	2/94	Users manual	Technical report	Verification and bench-marking	Validation
FECTRA	Two-dimensional or three-dimensional transport of radionuclides in porous rock	Site subsystem Engineered barriers subsystem Repository seals subsystem	• Dispersivities • Molecular diffusion coefficients • Radionuclide sorption coefficients • Output from MAGNUM-3D	3 3 2 --	3 2 1 --	2 1 1 --	Planned issuance in 1989	Planned issuance in 1989	To be determined	To be determined
MAGNUM-3D	Three-dimensional transient groundwater flow in fractured, porous rock	Site subsystem Engineered barriers subsystem Repository seals subsystem	• Hydraulic conductivities • Specific storages • Boundary conditions	2 2 2	1 2 1	1 2 1	Estey et al. (1985)	Planned issuance in 1988	Arnett et al. (1986)	Issuance of Plan in 1988
MAGNUM-3D-B	Three-dimensional transient groundwater flow in fractured, porous rock, considering bouyancy effects	Site subsystem Engineered barriers subsystem Repository seals subsystem	• Output from MAGNUM-3D-T • Hydraulic conductivities • Specific storages • Boundary conditions	2 2 2	2 2 1	2 2 1	Planned issuance in 1988	Planned issuance in 1988	Planned issuance 1988	To be determined
MAGNUM-3D-T	Three-dimensional conductive heat transport	Site subsystem Engineered barriers subsystem Repository seals subsystem	• Thermal conductivities • Specific heats • Temperature boundary conditions	4 4 4	3 3 3	2 2 2	Planned issuance in 1988	Planned issuance in 1987	Planned issuance 1988	To be determined
MAKSIMA-CHEMIST	Chemical reaction kinetics with radiolytic source terms	Engineered barriers subsystem	• Groundwater composition	TBD	TBD	TBD	To be determined	To be determined	To be determined	To be determined
RADIOL	Chemical reaction kinetics with radiolytic source terms	Engineered barriers subsystem	• Groundwater composition	TBD	TBD	TBD	To be determined	To be determined	To be determined	To be determined

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Table 8.3.5-10. Deterministic mathematical models and computer codes requiring significant development (sheet 2 of 2)

Model and code	Process(es) to be modeled	Subsystem application	Input parameters[a] from field and laboratory testing	Amount or source of data required[b] for input parameters and date required[c]			References and status[d]			
				5/88	6/89	2/94	Users manual	Technical report	Verification and bench-marking	Validation
PATH-3D	Three-dimensional groundwater flow and radionuclide transport	Site subsystem Engineered barriers subsystem Repository seals subsystem	• Output from MAGNUM-3D including hydraulic conductivity • Effective porosity	-- 2	-- 2	-- 2	Planned issuance in 1988	Planned issuance in 1988	Planned issuance in 1988	Not applicable
PORFLO-3D	Three-dimensional groundwater flow, heat transport, and radionuclide transport	Site subsystem Engineered barriers subsystem Repository seals subsystem	See PORFLO (see Table 8.3.5-6)				Planned issuance in 1988	Planned issuance in 1988	Planned issuance in 1988	Issuance of Plan in 1989
GEOTHER	Groundwater flow and heat transport	Engineered barriers subsystem	See PORFLO (see Table 8.3.5-6)	--	--	--	Planned issuance in 1988	Planned issuance in 1988	To be determined	To be determined

NOTE: Items designated by (--) are not applicable.

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[a]Other input parameters are required (e.g., half-life, grid size, waste age, barrier thickness, and thermal output). However, such parameter values can be assigned independently of the findings of site-specific laboratory or field testing or other site-specific research.

[b]Quality of data is expressed in relative terms with 1 being a higher quality than 5. Judgments of data quality that is required are subjective but are based on apparent sensitivity of model results to input parameter values.

5 = Data based on literature review with few, if any, site-specific measurements.
4 = Sufficient data to establish site-specificity of the expected value.
3 = Sufficient data to establish a range of site-specific values.
2 = Sufficient data to infer an approximate probability distribution or an approximate representative value.
1 = Sufficient data to establish a probability distribution or a single, representative value with high confidence.

[c]Date that a given quality of data for a specific parameter is required based on programmatic schedules for assessing performance with a given level of confidence derived from the allocated reliability goals. Schedule is subject to change.

[d]Reports on probabilistic and (or) three-dimensional variants of existing models and codes may be issued as updates of parent model and code reports. All dates are based on fiscal year beginning October 1.

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- Volumetric and (or) point sources.
- Specification of concentration, no flux, or flux boundary conditions.

The BWIP plans publication of a user manual and technical report in FY 1989. Dates for documentation of code verification and benchmark testing and plans for model validation have not yet been defined.

8.3.5.5.1.2 MAGNUM-3D

MAGNUM-3D will solve a three-dimensional form of the groundwater flow equation by numerical procedures that are the same as those used by MAGNUM-2D. MAGNUM-3D is limited to isothermal conditions. A version of MAGNUM-3D currently being developed (Section 8.3.5.5.1.3) will incorporate three-dimensional thermal-buoyancy effects.

MAGNUM-3D is based on the continuum theory of porous media and represents highly jointed rock as being equivalent to a porous media. Some of the important features of MAGNUM-3D are as follows:

- Uses quadratic-basis functions to depict complex geometry and rapid changes in the head field.
- Simulates complex three-dimensional geometries by using various three-dimensional isoparametric finite elements (e.g., triangular prisms and "brick" elements).
- Treats different types of boundary conditions (e.g., specified head and (or) fluxes).
- Calculates a three-dimensional flow field for input to pathline and transport computer codes and mathematical models.

A user manual for MAGNUM-3D has been prepared (Estey et al., 1985). Preliminary verification and benchmark testing of the current version of the computer code and mathematical model have been completed and are incorporated in a verification and benchmarking report (Arnett et al., 1986). The BWIP will issue plans in FY 1988 for validation of MAGNUM-3D.

MAGNUM-3D is undergoing development and testing to incorporate two-dimensional joint elements similar to the line elements of MAGNUM-2D. In addition, capability is being incorporated to allow for components of hydraulic conductivity not aligned with the coordinate axes. Completion of this effort and testing of the modified version of MAGNUM-3D are planned for FY 1988. (FECTRA and PATH-3D are also being updated to reflect the new features being incorporated into MAGNUM-3D and to maintain intercode compatibility of finite-element descriptions and flow fields.)

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8.3.5.5.1.3 MAGNUM-3D-B

The MAGNUM-3D-B version of MAGNUM-3D will include thermal buoyancy effects. The thermal field will be simulated by MAGNUM-3D-T and the results then input to MAGNUM-3D-B. The MAGNUM-3D-T and MAGNUM-3D-B codes will assume that thermal convection can be neglected in simulating thermal buoyancy effects, thus allowing fluid flow and heat transport equations to be decoupled. An initial version of MAGNUM-3D-B was developed during FY 1985. A user manual, technical report, and documentation of verification and benchmarking are expected to be issued in FY 1988. Plans for validation of MAGNUM-3D-B have not yet been defined.

8.3.5.5.1.4 MAGNUM-3D-T

The MAGNUM-3D-T version of MAGNUM-3D will solve the heat conduction equation. An initial version was developed during FY 1985, and MAGNUM-3D-T was updated in FY 1986. The BWIP plans to issue a user manual, technical report, and documentation of verification and benchmark testing in FY 1988. Plans for validation have not yet been defined.

8.3.5.5.1.5 PATH-3D

PATH-3D will calculate three-dimensional streamlines, pathlines, and travel times. It will be compatible with MAGNUM-3D (groundwater flow simulation) and use the following input:

- Same geometry file as MAGNUM-3D.
- Same material property file as MAGNUM-3D, except for the addition of the effective porosity of each material type.
- Hydraulic head file created by MAGNUM-3D.

PATH-3D will be a finite-element computer code and mathematical model that uses isoparametric elements with quadratic-basis functions. The code will simulate only advective components of groundwater flow.

Major features of PATH-3D are as follows:

- Groundwater velocities are computed from the spatial derivatives of the element-basis functions.
- Special methods are provided to eliminate potential particle oscillations at element boundaries.
- Graphic output of the streamlines and pathlines are provided.

Completion of a user manual and technical report is planned for FY 1988. Documentation of verification and benchmark testing for PATH-3D is planned for FY 1988 (see the description of modifications being made to MAGNUM-3D).

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8.3.5.5.1.6 PORFLO-3D

Development of a three-dimensional version of PORFLO is planned for FY 1988. When fully developed, it is anticipated that PORFLO-3D will be capable of solving the coupled equations of fluid flow and heat and mass transport in three dimensions.

PORFLO-3D will be employed to analyze performance of engineered barriers and repository seals subsystems with realistic three-dimensional features. A user manual will be published in FY 1988. A technical report and documentation of verification and benchmark testing of PORFLO-3D will be issued in FY 1988. Plans for validation of PORFLO-3D will be issued in FY 1989.

8.3.5.5.1.7 MAKSIMA-CHEMIST

The code MAKSIMA-CHEMIST is a chemical kinetics code being considered for use in the solution of the chemical kinetics equations with radiolytic source terms. Input for this code would consist of specification of the involved reactions, the rate constants governing the reactions at the anticipated temperatures, and the initial concentrations of the reactants.

Evaluation of the applicability of this code in the BWIP waste package modeling program is in an early stage. It is yet to be determined whether the existing documentation (Carver et al., 1979) is adequate and whether the code can be applied without modification.

8.3.5.5.1.8 RADIOL

The code RADIOL is a chemical kinetics code being considered for use in the solution of the chemical kinetics equations with radiolytic source terms. Input for this code would consist of specification of the involved reactions, the rate constants governing the reactions at the anticipated temperatures, and the initial concentrations of the reactants.

Evaluation of the applicability of this code in the BWIP waste package modeling program is in an early stage. It is yet to be determined whether the existing documentation is adequate and whether the code can be applied without modification.

8.3.5.5.1.9 GEOTHER

The GEOTHER code models two-phase groundwater flow in geologic formations. This code is based upon a previous computer code. The original code (Faust and Mercer, 1983) is one-dimensional and does not include a data base appropriate for the temperature regime expected near the waste packages.

The GEOTHER code is presently being modified to account for the three-dimensional nature of the repository and to cover the waste package temperature regime. A user manual and technical report will be issued in FY 1988. Dates for documentation verification and benchmark testing and for issuing plans for model validation have not yet been established.

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8.3.5.5.2 Probabilistic codes

The EPA (1986) requires that assessments of long-term repository performance incorporate uncertainties as a probability distribution of the predicted cumulative radionuclide releases. In response to this requirement, the BWIP has developed both Monte Carlo and finite-order stochastic mathematical models and numerical computer codes that probabilistically simulate long-term geologic repository performance.

The mathematical models and computer codes listed in Table 8.3.5-11 are employed in computer simulations for which results are expressed as cumulative probability distribution functions. Table listings and their annotated descriptions following the table are given alphabetically.

8.3.5.5.2.1 PCM-STAT

PCM-STAT will estimate the life of a waste container that is subjected to uniform corrosion using equations based on empirical data (Fish and Anantatmula, 1983; Sagar et al., 1984). Future documentation of PCM-STAT is planned in FY 1988. Needed development work includes solution of fundamental equations of electrochemistry.

A user manual, technical report, and documentation of verification of benchmark testing will be issued in FY 1988. Plans for validation have not yet been established.

8.3.5.5.2.2 PORMC

PORMC, when fully developed, will solve coupled two-dimensional equations of fluid flow and heat and mass transport. This capability will enhance the current capabilities of the deterministic PORFLO computer code and mathematical model. In PORMC, options for incorporating stochastic parameters are provided.

Such stochastic parameters can be incorporated either as univariate random variables sampled from their specified probability distribution functions or as spatially variable, correlated processes. Stratified sampling is used to sample the input distributions.

PORMC will likely be used for assessing performance of the engineered barriers and site subsystems. A partially completed version of PORMC is now being used to calculate groundwater travel time. This version solves only the pressure equations of the model for steady-state conditions. The groundwater travel times are obtained via a semianalytic method.

The BWIP plans to issue a user manual for PORMC in FY 1988. A technical report will be published in FY 1988. Dates for both documenting verification and benchmark testing and for issuing plans for model validation have not yet been set.

Table 8.3.5-11. Probabilistic mathematical models and computer codes requiring significant development

Model and code	Process(es) to be modeled	Subsystem application	Input parameters[a] from field and laboratory testing	Amount or source of data required[b] for input parameters and date required[c]			References and status[d]			
				5/88	6/89	2/94	Users manual	Technical report	Verification and bench-marking	Validation
PACLIFE	Life of waste container subjected to corrosion	Engineered barriers subsystem	Under development; to be determined	--	--	--	Planned issuance in 1988	Planned issuance in 1988	To be determined	To be determined
PCM-STAT	Life of waste container subjected to uniform corrosion	Waste container component Engineered barriers subsystem	Under development; to be determined	--	--	--	Planned issuance in 1988	Planned issuance in 1988	To be determined	To be determined
PORMC	Two-dimensional groundwater flow, heat transport, and radionuclude transport using distributed parameters	Engineered barriers subsystem Site subsystem Repository seals subsystem	See PORFLO (see Table 8.3.5-6)	--	--	--	Planned issuance in 1988	Planned issuance in 1988	To be determined	To be determined
PORMC-SF-3D	Three-dimensional, steady-state groundwater flow	Site subsystem	• Effective porosities • Hydraulic conductivities	2 2	1 1	1 1	Planned issuance in 1988	Planned issuance in 1988	To be determined	To be determined
SPAM	Two-dimensional groundwater flow, radionuclude transport, and dose calculations using distributed parameters	Site subsystem	• Dispersivities • Molecular diffusion coefficients • Radionuclide sorption coefficients • Water flow parameters • Dose concentration coefficients	3 3 2 2 2	3 2 1 1 2	2 1 1 1 2	Planned issuance in 1988	Planned issuance in 1988	To be determined	To be determined

NOTE: Items designated by (--) are not applicable.

[a]Other input parameters are required (e.g., half-life, grid size, waste age, barrier thickness, and thermal output). However, such parameter values can be assigned independently of site-specific laboratory or field testing findings or other site-specific research.

[b]Quality of data is expressed in relative terms with 1 being a higher quality than 5. Judgments of data quality that is required are subjective but are based on apparent sensitivity of model results to input parameter values.

5 = Data based on literature review with few, if any, site-specific measurements.
4 = Sufficient data to establish site-specificity of the expected value.
3 = Sufficient data to establish a range of site-specific values.
2 = Sufficient data to infer an approximate probability distribution or an approximate representative value.
1 = Sufficient data to establish a probability distribution or a single, representative value with high confidence.

[c]Date that a given quality of data for a specific parameter is required based on programmatic schedules for assessing performance with a given level of confidence derived from of allocated reliability goals. Schedule is subject to change.

[d]Reports on probabilistic and (or) three-dimensional variants of existing models and codes may be issued updating of parent model and code reports. All dates are based on fiscal year beginning October 1.

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8.3.5.5.2.3 PACLIFE

PACLIFE, when fully developed, will provide bounding estimates of the life of a waste container based upon transport considerations. The equations for kinetics, mass transport of corrosion products and reactants, and heat transfer are solved, from which a time-dependent corrosion rate can be back calculated.

Some parameters will be treated stochastically in PACLIFE. The stochastic parameters will be incorporated by random sampling of specified univariate probability distributions.

A user manual and technical report will be issued in FY 1988. Dates for documenting verification and benchmark testing and for issuing plans for model validation have not yet been established.

8.3.5.5.2.4 PORMC-SF-3D

PORMC-SF-3D will be a three-dimensional version of PORFLO. It will solve the steady-state, three-dimensional groundwater flow equation and will stochastically analyze groundwater flow and groundwater travel times in a bounded domain. Issuance of a user manual and technical report is planned for FY 1988. Dates for verification and benchmarking of PORMC-SF-3D have not yet been established.

8.3.5.5.2.5 SPAM

When fully developed, the SPAM computer code will be used for two purposes: (1) to assess system performance in isolating radionuclides from the accessible environment and (2) to calculate doses to individuals as required by 40 CFR 191.15 (EPA, 1986). The SPAM code will be used to calculate the cumulative radionuclide flux at a specified distance from the edge of the repository and compare that flux with the limit specified by 40 CFR 191.

The SPAM computer code requires substantial development and will eventually replace the EPASTAT code, which is not capable of dose computations. The development of SPAM is scheduled for FY 1988, with final documentation and verification planned for FY 1989.

8.3.5.5.3 Use of expert judgment

The use of expert judgment has been explained in Section 8.3.5.4.3. Plans for FY 1987 in this area are described below.

- A method will be developed allowing expert opinion expressed in probabilistic terms (e.g., through probability encoding) to be combined with observed site data. This will allow preliminary performance assessments to be made before more site-specific data

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become available from site characterization. This is especially important for parameters for which few values can be obtained because of time or budgetary constraints.

- An expert review of the mathematical basis of at least one performance assessment model is planned. This will serve as a first step toward validation of the model.

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SITE CHARACTERIZATION PLAN

Chapter 8 - SITE CHARACTERIZATION PROGRAM

Section 8.4

Planned Site Preparation Activities

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8.4 PLANNED SITE PREPARATION ACTIVITIES

The Nuclear Waste Policy Act of 1982 (NWPA, 1983, Section 113) and 10 CFR 960 (DOE, 1987a) require that the U.S. Department of Energy (DOE) carry out appropriate site characterization activities to evaluate the suitability of a candidate site for the location of a nuclear waste repository. These activities include borings, surface excavations and related testing, exploratory shafts excavation, subsurface lateral excavations, and in situ testing.

The planned tests, studies, and analyses to be conducted as part of site characterization activities are presented in Section 8.3. Study plans are used to provide details of these tests, studies, and analyses. The relationship of the Site Characterization Plan (SCP) to the study plans is discussed in Section 8.0. Study plans that require the use of the Exploratory Shaft Facility to fulfill testing requirements will be made available by the time the SCP is issued to the public. Any additional individual study plans will be made available at least 6 mo prior to conducting any tests required by the study plans.

The objectives of this section are to describe (1) site preparation activities required to support site characterization activities and (2) design and construction plans for the Exploratory Shaft Facility in sufficient detail to evaluate the following:

- Can the planned set of tests (see Section 8.3) be physically supported?
- Is the planned sequencing of tests appropriate?
- Has adequate flexibility been incorporated into design and construction plans?
- Will construction of, or testing in, the exploratory shafts and the underground test facility adversely impact the waste isolation integrity of the proposed repository?

The technical basis for this section at the present time consists of two conceptual design reports for the Exploratory Shaft Facility (RKE/PB, 1984; 1986) and the site characterization testing program described in Section 8.3.

A design basis study (WHC, 1988), which modifies some elements of the conceptual design reports, will be issued in early 1988. The objective of the design basis study is to evaluate the following:

- Design basis values for water and methane inflow.
- Flexibility of the design to support potential changes in program direction.

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- Cost and schedule impacts that could result if the design were changed to comply with gassy mine regulations.

- Cost, schedule, advantages, and disadvantages of a larger second shaft (Exploratory Shaft 2).

As a result of this study, the need for a larger amount of ventilation air and consequently a larger second exploratory shaft was identified. The formal recommendation for the 3.0- to 3.6-m (10- to 12-ft) finished inside diameter of Exploratory Shaft 2 will be based on safety (NWPA, 1983, Section 113(a) and 113(c)(1)), cost, schedule, ventilation requirements, flexibility, other functional requirements, and risk. A specific shaft size will be proposed early in the definitive design stage.

The added ventilation requirements and the increased shaft size is not reflected in this section. A larger diameter shaft is also not reflected in the Phase I repository development schedule discussed in Section 6.2.6.1.4. The possible use of this larger diameter exploratory shaft for one of the eleven repository shafts is also not discussed in Section 6.2.2.4. Changes to this and the referenced design sections will be made prior to issuance of the Site Characterization Plan.

Potential environmental impacts resulting from Exploratory Shaft Facility construction and operation were addressed in the Environmental Assessment (DOE, 1986a). Future environmental concerns will be addressed via the environmental monitoring and mitigation plan. Also, sufficient space will be provided between test locations within the Exploratory Shaft Facility to accommodate thermomechanical rock disturbances such as those defined by the U.S. Nuclear Regulatory Commission (NRC) in their technical position paper on the disturbed rock zone (NRC, 1986a).

Surface-site preparation activities are discussed in Section 8.4.1, and design and construction plans for the Exploratory Shaft Facility are discussed in Section 8.4.2. Also, a description of the Exploratory Shaft Facility, which is to be used for the in situ testing portion of the site characterization program, is provided in Section 8.4.2. This description includes a layout of planned excavations (including design dimensions), details of construction, the effect of testing on the waste isolation integrity of a future repository, and flexibility features to be incorporated into the design and construction activities. There is an integral link between the Exploratory Shaft Facility design and construction plans presented in this section and the planned tests and studies in Section 8.3; therefore, to avoid needless replication of text, extensive referencing between the two sections will be provided.

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8.4.1 SURFACE SITE PREPARATION ACTIVITIES

The surface activities needed to prepare the Hanford Site for the site characterization effort are described in this section. These activities include the following:

- Preparation of the ground surface at the exploratory shaft site (Section 8.4.1.1).
- Construction of utilities for surface facilities (Section 8.4.1.2).
- Provision of access and security (Section 8.4.1.3).
- Preparation of surface borehole drilling sites (Section 8.4.1.4).
- Construction of surface facilities (Section 8.4.1.5).

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8.4.1.1 Surface site preparation for Exploratory Shaft Facility construction

The Exploratory Shaft Facility will be located near the west boundary of the 200 West Area of the Hanford Site within the Cold Creek Syncline. The exploratory shaft site, utility interfaces, and access roads are shown in Figure 8.4-1. The surface facilities and their relation to the subsurface test facility, together comprising the Exploratory Shaft Facility, are shown in Figure 8.4-2.

Roads and gravel-surfaces areas provide routes for traffic from the access road entrance to the working and parking areas and to other parts of the Exploratory Shaft Facility. They are designed to accommodate the required vehicular quantities and weights. Access roads outside the Exploratory Shaft Facility fence are discussed in Section 8.4.1.3.

The area within the Exploratory Shaft Facility fence, excluding the mud pits and the much pile areas, is surfaced with compacted, pit-run gravel--305 mm (12 in.) thick in heavy traffic areas and 203 mm (8 in.) thick elsewhere. This type of surface improves the capability of providing access to every area of the Exploratory Shaft Facility site during its construction and operation. The mud pits are lined with bentonite. Any topsoil removed will be stored in an environmentally acceptable manner until needed to decommissioning activities.

The drill rig pads for the two shafts, Exploratory Shaft 1 and Exploratory Shaft 2, will be located near the Cold Creek channel. The shaft collars will be designed so they are protected from the probable maximum flood. The remaining exploratory shaft surface facilities will be designed for a 50-yr, 24-h duration, thunderstorm (probable maximum precipitation). The Exploratory Shaft Facility site will be graded to provide a 2% slope away from

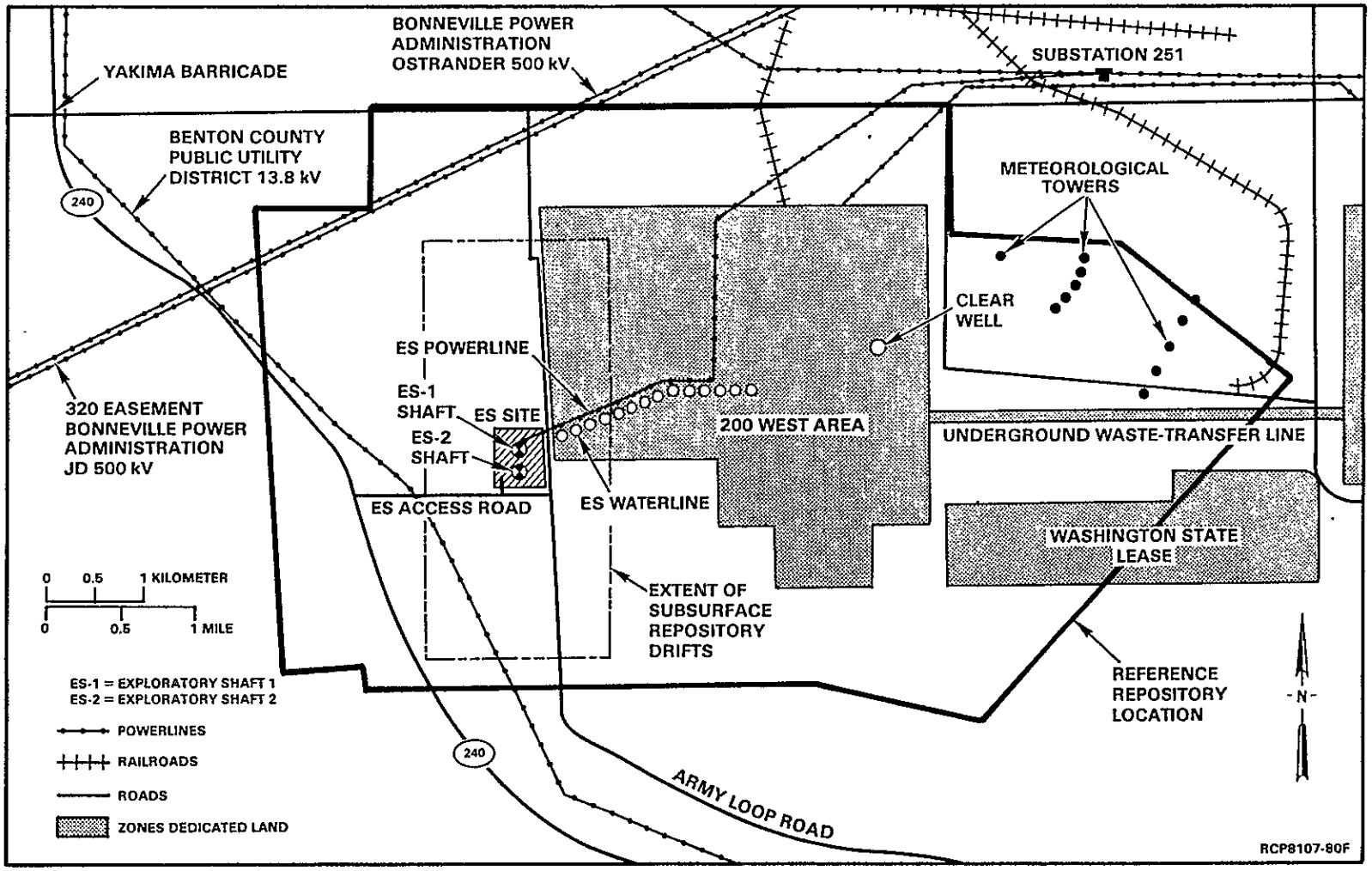

Figure 8.4-1. Exploratory Shaft Facility location.

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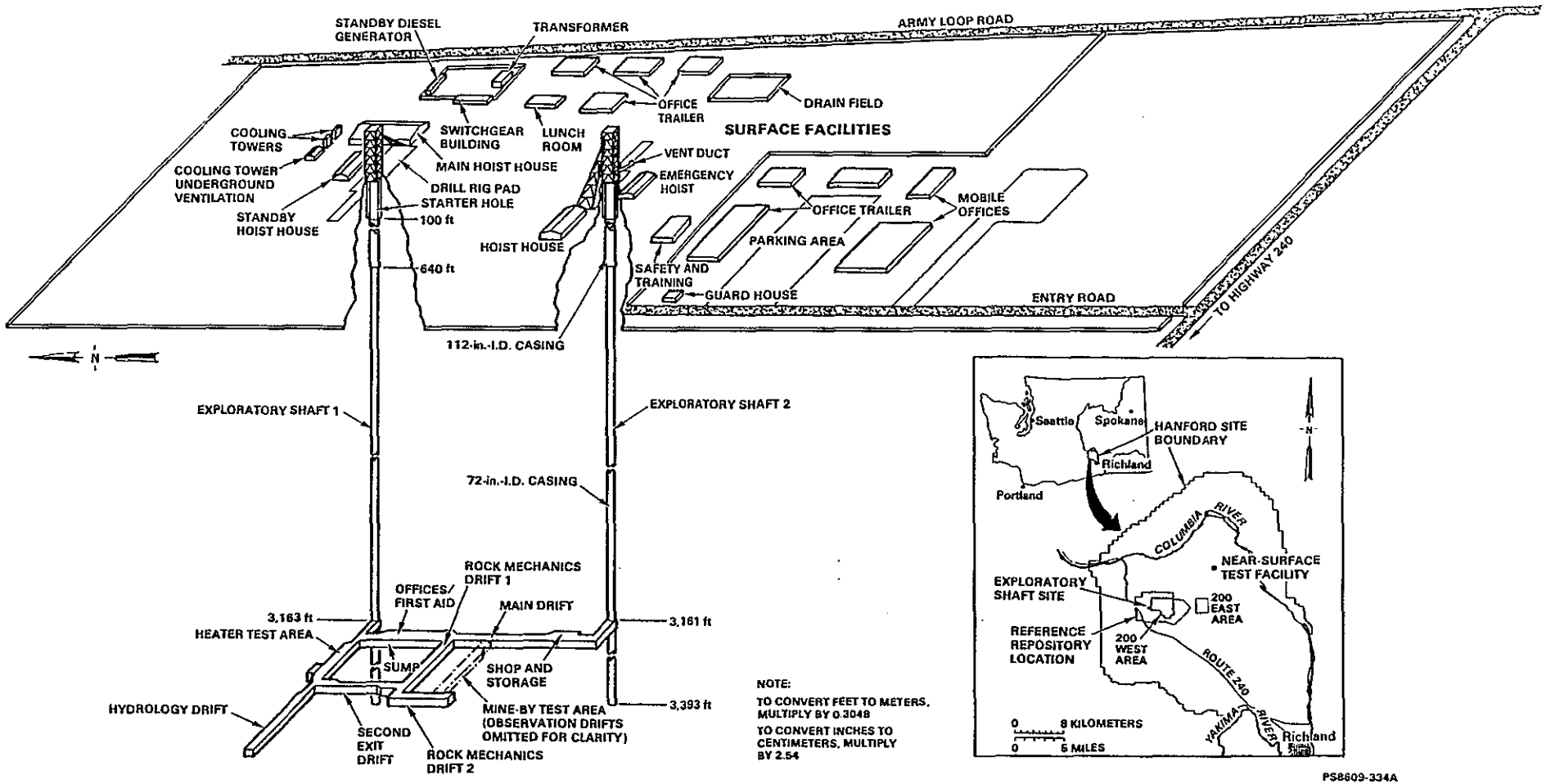

Figure 8.4-2. Exploratory Shaft Facility surface layout (operating phase).

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all buildings and shafts. Surface drainage is sheet-flow directed away from buildings to roadside ditches or natural drainage ways. From observation of the surrounding area, erosion of material by water runoff along embankments or spoil slopes is not expected to be great enough to warrant the extra cost of special slope treatment. If wind erosion and dust become major concerns, they will be controlled by chemical treatment, wind barriers, wetting, and (or) traffic restrictions, as appropriate.

Soils under foundations and slabs will be stabilized as necessary, typically by compaction of subgrades and fill materials to 95% of maximum density. Utility trenches will be shored, sheeted, and braced in accordance with Washington State requirements. All backfill placed in utility trench excavations within the limits of buildings and paved areas will consist of sand or sand and gravel compacted to at least 95% of maximum density. The existing borrow pit for fill materials is located approximately 3.2 km (2 mi) north of the Exploratory Shaft Facility.

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8.4.1.2 Utilities system preparation

A number of utilities for surface facilities are required to support the site characterization and exploratory shaft testing program. They include the following:

- Water for drilling fluids, ventilation air cooling, equipment cooling, personnel usage, and fire protection.
- Sewage and other wastewater disposal from surface facilities.
- Electrical power for all loads during Exploratory Shaft Facility construction and subsequent testing, including provisions for emergency onsite power generation.
- Communications to support construction, safety, and testing, including telephones, radios, intercoms, alarms, and computer networks.
- Compressed air to assist lifting the drill mud and cuttings out of the drill holes and to power certain other equipment.
- Heating, ventilation, and air conditioning of surface facilities.

8.4.1.2.1 Water Systems

The water system at the exploratory shaft site is a pressurized, combined system that distributes potable, process, and fire-protection water in an underground piping network. The system is designed to accommodate a projected peak demand of 3,650 L/min (965 gal/min).

Water for the exploratory shaft water system comes from the 200 West Area and is distributed to demand points at the Exploratory Shaft Facility site. The design requirements of the water system are described in RKE/PB (1984; 1986). Categories of water usage are as follows:

- Potable water used for drinking, cooking, and testing where water purity is required.
- Process water used for drilling, grout and cement preparation, dust suppression, mud preparation, surface sewage systems, and heat exchanger cooling.
- Water used for fire-protection purposes through hydrants and sprinkler systems.

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8.4.1.2.2 Sewage systems

A sewage system will be provided in accordance with the applicable design bases (RKE/PB, 1984; 1986). Domestic wastewater and sewage is collected and transported in the sanitary sewage system by gravity in an underground system. The pipe system discharges all collected materials into underground septic tanks that subsequently decant liquids into drain fields.

Wastewater is collected from fixtures such as tank-operated water closets, lavatories, shower stalls, drinking fountains, urinals, and kitchen sinks. The essential features of this collection system are the PVC collection pipe with manholes and cleanouts, septic tank, distribution box (from the septic tank), and perforated drain pipe in the drain field.

Drain-field lines are placed above 152-mm- (6-in.-) deep beds of 25.4-mm- (1-in.-) maximum-size gravel in 0.6-m- (2-ft-) wide trenches for percolation into the soil. The drain pipe is standard, without special structural requirements.

8.4.1.2.3 Electrical systems

Electrical systems for the exploratory shaft include normal power, standby power, uninterruptible power, surface distribution, shaft underground distribution, and building/site lighting and power. These systems will receive normal power service from the exploratory shaft primary supply via an overhead, single 13.8-kV circuit that extends from the Hanford substation (251 W) to the exploratory shaft site. Primary power for equipment is transformed for local distribution and use at the following voltages:

- 2,400 V, 3 phase, 60 Hz.
- 600 V, 3 phase, 60 Hz.

- 480 V, 3 phase, 60 Hz.
- 208 V/120 V, 3 phase (Wye), 4 wire, 60 Hz.
- 240/120 V, single phase, 3 wire, 60 Hz.

Standby power is a source of power that is activated upon loss of normal power to provide power to certain components until normal power is restored. Standby power will be provided by diesel generators to service such items as the shaft dewatering pumps, Exploratory Shaft 1 and Exploratory Shaft 2 shaft hoists, and standby ventilation equipment. The standby power generated onsite by the diesel generators is provided at 2,400 V, 3 phase, 60 Hz.

Instrumentation and computer systems that have uninterruptible power requirements have individual power supply systems that meet power needs when either normal or standby power systems are unavailable.

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8.4.1.2.4 Communications systems

The communications system will include the telephone network for public, Federal Telecommunications System, and plant phones; two-way radios and site alarms; the public address and paging system; local intercoms and sound-powered communication; computer networks and data systems; and the main and standby shaft conveyance independent radio and signaling systems. All communication systems are backed by uninterruptible power that will supply power needs when either normal or standby power systems are unavailable. Underground communication will be conducted by telephone, intercom/paging, sound-power communication, and data acquisition systems. Auxiliary communication systems include two-way portable radios (hand-held and in vehicles) and main and standby shaft conveyance radio and signaling systems that work on demand from any location in the shaft.

8.4.1.2.5 Compressed air system for equipment

Compressed air is provided for the drill rig by portable equipment to be used during the drilling operation. Compressed air for surface and subsurface usage is supplied from two air compressors in the hoise house, each capable of supplying the maximum expected operational demand to the subsurface--0.28 m^3/s (600 ft^3/min). The second unit operates alternately with the first unit for greater system availability. Further description of this system as it relates to subsurface mining and testing operations is contained in Section 8.4.2.2.2.

8.4.1.2.6 Heating, ventilating, and air conditioning systems

Systems will be provided to ventilate, heat, cool, and filter air for personnel habitability and equipment operability. Design values are identified in RKE/PB (1984; 1986). The hoise houses (main and standby), the

warehouse, and the switchgear building use a combination of electric heaters, roof exhaust fans/ventilators, and evaporative coolers to meet the design values. Air conditioning is required only by trailer units used for offices and other personnel support facilities. Trailer units located at the Exploratory Shaft Facility will have self-contained ventilation, air conditioning, and heating systems.

8.4.1.3 Access and security systems preparation

Access to the Exploratory Shaft Facility will be via a north-south paved road (Fig. 8.4-3). South of the Exploratory Shaft Facility, this access road will join an east-west paved road to be constructed between State Route 240 and Army Loop Road. Public access will be from State Route 240; access via Army Loop Road will be limited to authorized personnel.

Security measures will include perimeter lighting and a 2.1-m- (7-ft-) high chain link fence topped with barbed wire surrounding the Exploratory Shaft Facility (see Fig. 8.4-3). The access road will enter through a gate in the security fence at the southwest corner of the Exploratory Shaft Facility personnel. Access by traffic entering from State Route 240 will be controlled by Hanford Patrol personnel as will traffic from Army Loop Road.

8.4.1.4 Surface borehole sites development

As part of the site characterization program, the Basalt Waste Isolation Project (BWIP) will continue the hydrology test program (described in Section 8.3.1.3) with additional exploratory test boreholes drilled from the surface. The existing test boreholes near the reference repository location are shown in Figure 8.4-4. Although the borehole surface sites vary from one are shown in Figure 8.4-4. Although the borehole surface sites vary from one to another, the following describes a typical site preparation: a site approximately 0.4 ha (1 acre) in size is cleared and graded; a compacted gravel drilling-support pad approximately 46 m by 92 m (150 ft by 300 ft) is installed; and, an unlined mud pit approximately 6 m by 9 m by 1 m (20 ft by 30 ft by 4 ft) is constructed.

Mud pits will be backfilled in an environmentally acceptable manner on completion of borehole use. At the conclusion of testing, boreholes will be sealed, plugged, and decommissioned as described in Section 6.2.8.3 (repository closure) or Section 8.7.2.1 (surface borehole closure and decommissioning).

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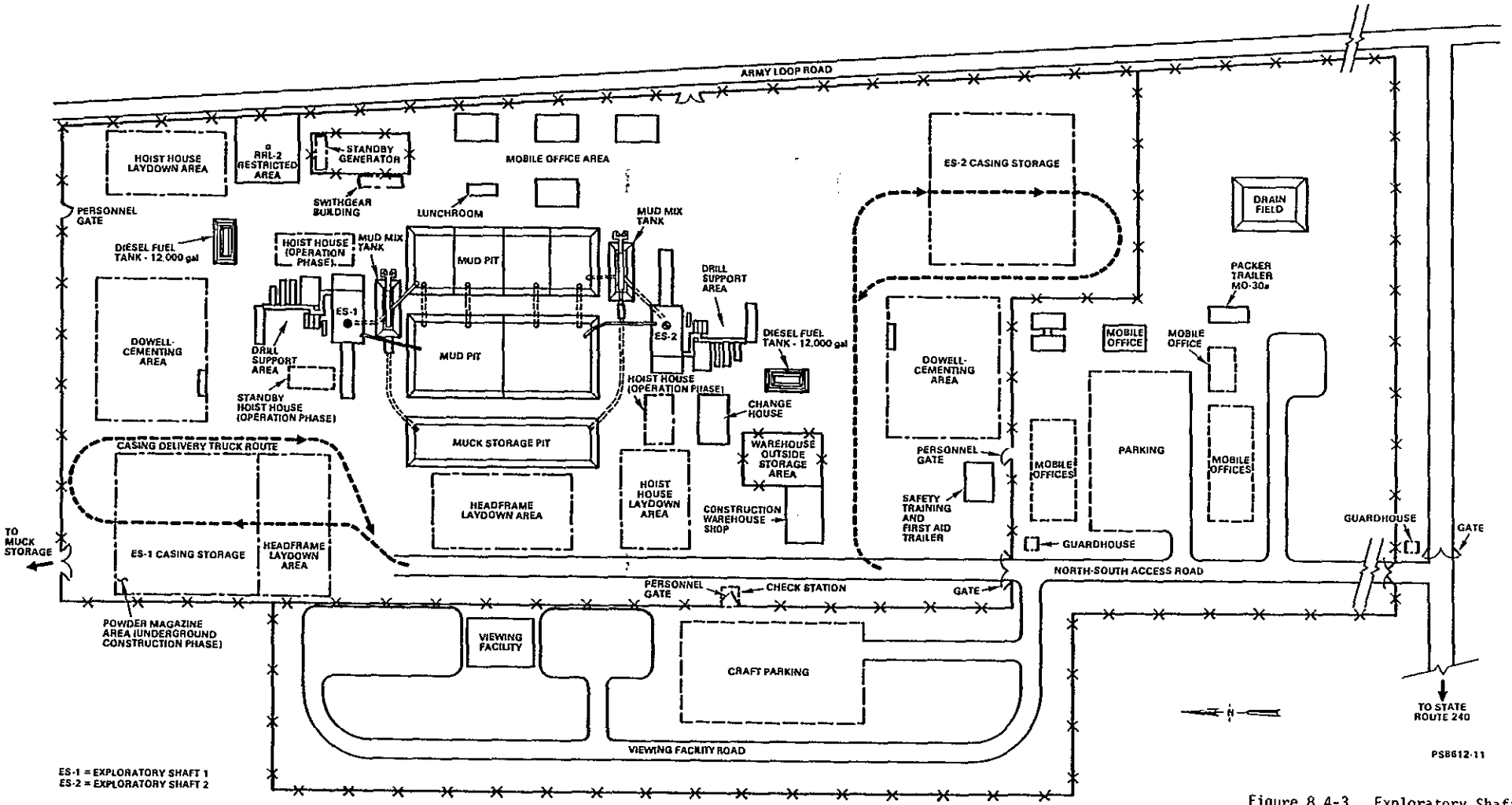

Figure 8.4-3. Exploratory Shaft Facility surface layout.

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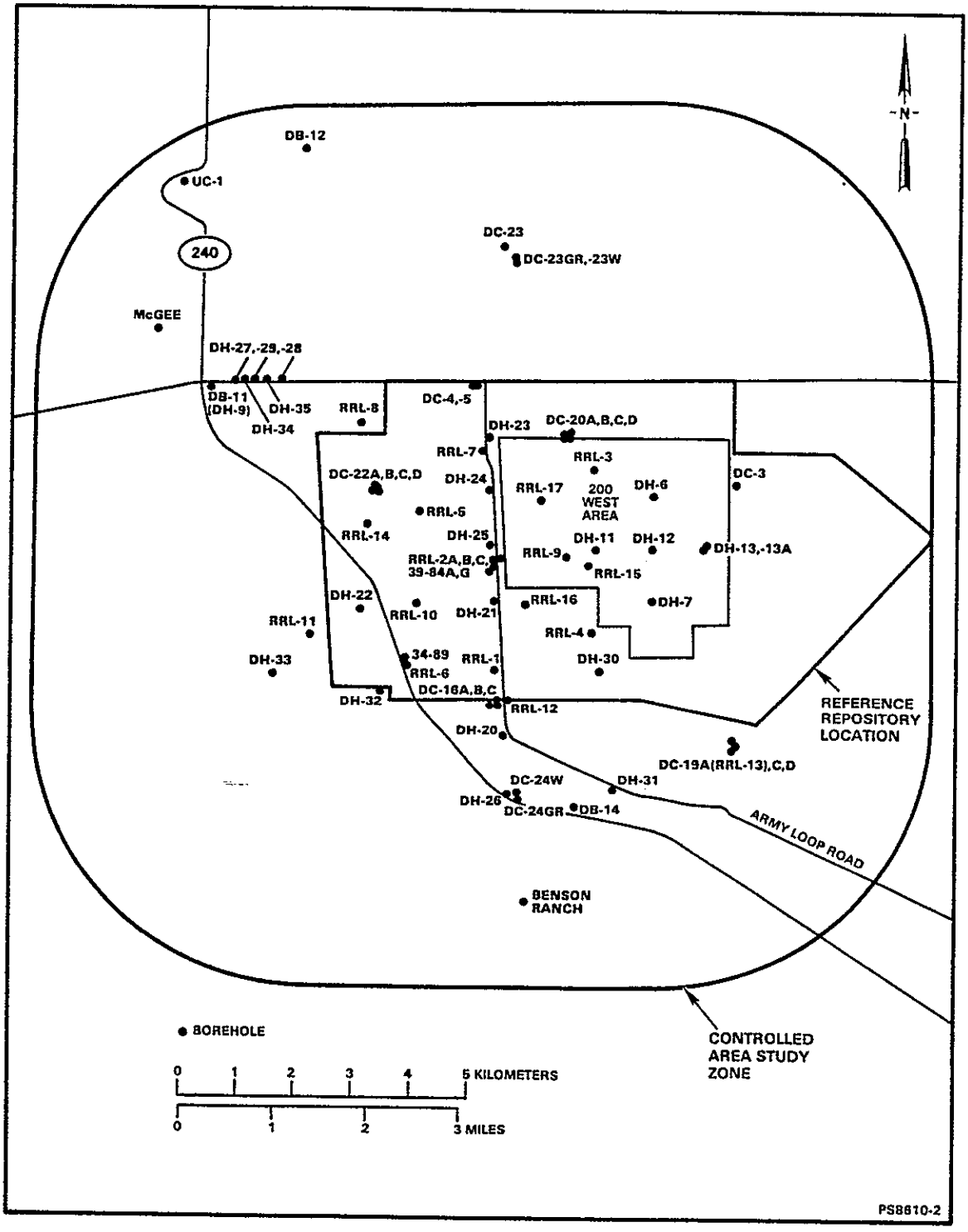

Figure 8.4-4. Surface borehole locations.

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8.4.1.5 Surface facilities development

Facilities required to support exploratory shaft construction and test operations compose the major part of the Exploratory Shaft Facility (see Fig. 8.4-3). The Exploratory Shaft Facility is arranged to provide convenient access to the shafts, as well as adequate facilities and working space during both the drilling and operational periods. In the initial phase, space requirements of the drilling contractor receive priority. The Exploratory Shaft Facility arrangement will accommodate expansion of the operational facilities should it become necessary. The Exploratory Shaft Facility is served by a main road along its west side and connecting roads, as shown in Figure 8.4-3. These roads provide access to the office trailer area at the south end of the exploratory shaft site, the office trailer area on the east side, the two exploratory shafts, the casing storage areas, and the warehouse.

Exploratory Shaft 2, as presently located, is 152.4 m (500 ft) south of Exploratory Shaft 1. This location allows the same mud pits to be used for the drilling of both shafts. The mud pit required for shaft drilling is divided into six compartments, two large and four small, so that the drill cuttings in the circulated mud can be removed. Settled cuttings will be removed periodically by equipment located at the western edge of the pit. The pits will be of sufficient capacity to properly clean the circulating mud and store the entire working mud volume. The existing Exploratory Shaft 1 mud pits will be converted at the end of Exploratory Shaft 1 drilling to support the drilling for Exploratory Shaft 2. The conversion requires that all pit compartments be thoroughly cleaned, pit inflow and discharge lines be shifted from the north to the south ends of the appropriate pit compartments, and a change be made in the order in which control gates and weirs are used. No physical change in the compartment layout of the mud pit is required. The mud pits will be decommissioned (backfilled) after shaft construction is completed, as specified in Section 8.7.2.6.

During Exploratory Shaft 1 drilling, a space west of the drill rig is provided by transfer and handling of the shaft casing (see Fig. 8.4-3). The storage area for the casing is located adjacent to the casing-handling area. A space is provided north of the drill rig for cement-pumping trucks. Large cementing equipment (storage silos and cement-handling trucks) are located north of the area provided for pumping trucks. Drilling air compressors, contractor trailers, and contractor water tanks are located northeast of the drill rig.

For Exploratory Shaft 2 drilling, a space is provided east of the drill rig for the transfer and handling of the shaft casing. The storage area for the casing is southeast of the casing-handling area. The storage area for large cementing equipment will be located in an area west of the drill rig. Drilling air compressors, contractor trailers, contractor water tanks, and dry drilling-mud storage areas are south and southeast of the drill rig. Mud-mixing tanks and facilities are north of and between the mud pits and the drill rig.

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Basalt chips (much) removed during drilling and subsurface excavation will be stored near the Exploratory Shaft Facility using methods described in the Environmental Assessment (DOE, 1986a, Sections 4.2.1.2 and 4.2.1.3).

The transformer yard and switchgear buildings are located east of the Exploratory Shaft 1 hoist house, near the terminus of the incoming power line. This is a central location with respect to electrical loads, the largest of which arise from the drill rigs and shaft hoists. A buried, 18,927-L (5,000-gal) diesel fuel storage tank will be placed north of the standby generator, outside the transformer yard fence. The hoist house for Exploratory Shaft 1 will be located so that the centerline of the hoist drum is approximately 32 m (105 ft) east of the Exploratory SHaft 1 centerline. The hoist house for Exploratory Shaft 2 will be located so that the centerline of the hoist drum is approximately 32 m (105 ft) west of the Exploratory Shaft 2 centerline.

Several trailers (allocated for offices, visitors, and personnel training) are located south of the Exploratory Shaft 2 drill rig outside the southern boundary of the construction area. Additional office trailers and a testing trailer are located east of the mud pit. Additional office trailers and a testing trailer are located east of the mud pit. The former group of trailers will be separated from the construction area by a fence with a vehicle gate and a personnel gate. The fence will separate the construction activity from the office, training, and visitor activity and will keep all personal vehicular traffic out of the construction area. The parking area for all personal vehicles is planned to be located next to the main access road and south of the training and visitor trailers.

The warehouse, as presently envisioned, will be located southwest of the Exploratory Shaft 2 main hoist house to provide ready access for deliverables and for site distribution. The change house will be located near the Exploratory Shaft 2 for convenient access to the subsurface facility and personnel gates. Both the warehouse and change house will be located away from the cementing equipment and explosive storage areas.

During the subsurface construction period (after completion of the Exploratory Shaft 1 shaft), an explosives storage magazine and barricade will be provided northwest of the mud pit in the area originally used for Exploratory Shaft 1 casing storage (see Fig. 8.4-3). This location provides the safety distances required by the Washington State Division of Industrial Safety and Health. Blasting detonators will be stored adjacent to the explosives storage magazine in accordance with applicable regulations.

Of the facilities functionally described in this section, several are preengineered, insulated metal buildings supported on reinforced concrete foundations and slabs. They include main hoise houses (one each for Exploratory Shaft 1 and Exploratory Shaft 2), a standby hoist house for Exploratory Shaft 1, a switchgear building, and a warehouse. Each meets the applicable portions of the National Fire Code and other appropriate standards.

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8.4.2 UNDERGROUND TEST FACILITY PREPARATION ACTIVITIES

The overall function of the Exploratory Shaft Facility is to provide access to the Cohassett flow for in situ testing to resolve major questions of site suitability that cannot be resolved from the surface or through small-diameter boreholes. The design and construction methods of the Exploratory Shaft Facility have been developed specifically to support the planned in situ testing.

The layout and construction of the two exploratory shafts and the associated underground test facilities are described in this section. This description will include the types and locations of in situ tests presently identified and will identify the flexibility of the Exploratory Shaft Facility to accommodate additional testing.

The Exploratory Shaft Facility is made up of the following, listed in the approximate sequence of their construction (Fig. 8.4-5, 8.4-6, and 8.4-7):

- Exploratory Shaft 1 shaft ((1.8-m (6-ft) finished inside diameter, to a depth of approximately 1,024 m (3,360 ft)).
- Exploratory Shaft 1 breakout and shaft station at the candidate repository horizon at the 964-m (3,164-ft) level.
- Exploratory Shaft 2 shaft (3.0- to 3.6-m (10- to 12-ft)) finished inside diameter, to a depth of approximately 1,024 m (3,360 ft)), is located 152.4 m (500 ft) south of Exploratory Shaft 1. The finished inside diameter of this shaft is presently being evaluated to determine its ability to meet present operational and flexibility requirements. A specific shaft size will be proposed early in the definitive design stage.
- Exploratory Shaft 2 breakout and shaft station at the candidate repository horizon at the 963-m (3,161-ft) level.
- Main drift 4 m by 2.7 m (13 ft by 9 ft) connecting the two shaft stations.
- Drifts and raises for hydrology, rock mechanics, mine-by, and observation/instrumentation galleries.

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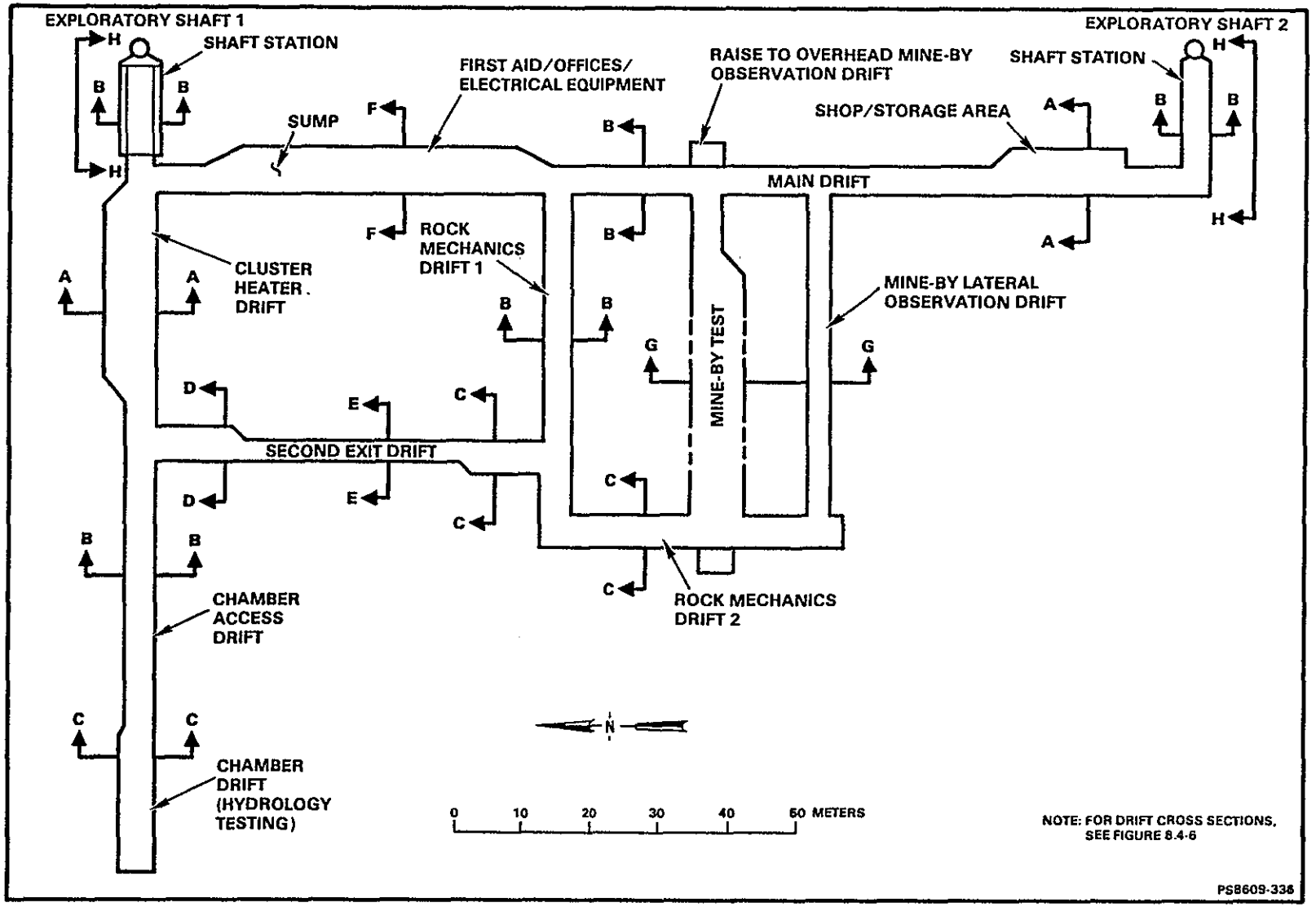

Figure 8.4-5. Exploratory Shaft Facility underground layout.

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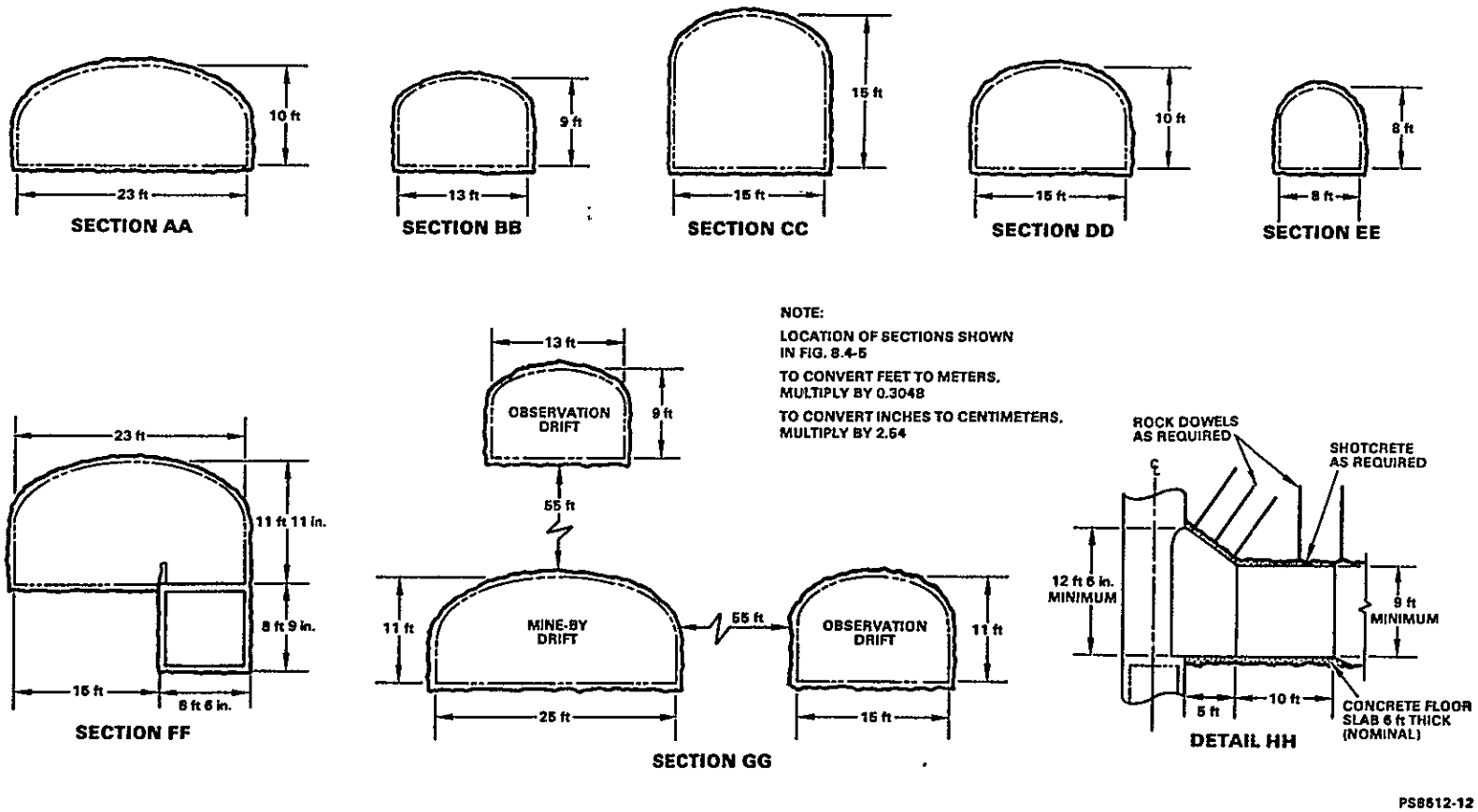

Figure 8.4-6. Typical drift cross sections.

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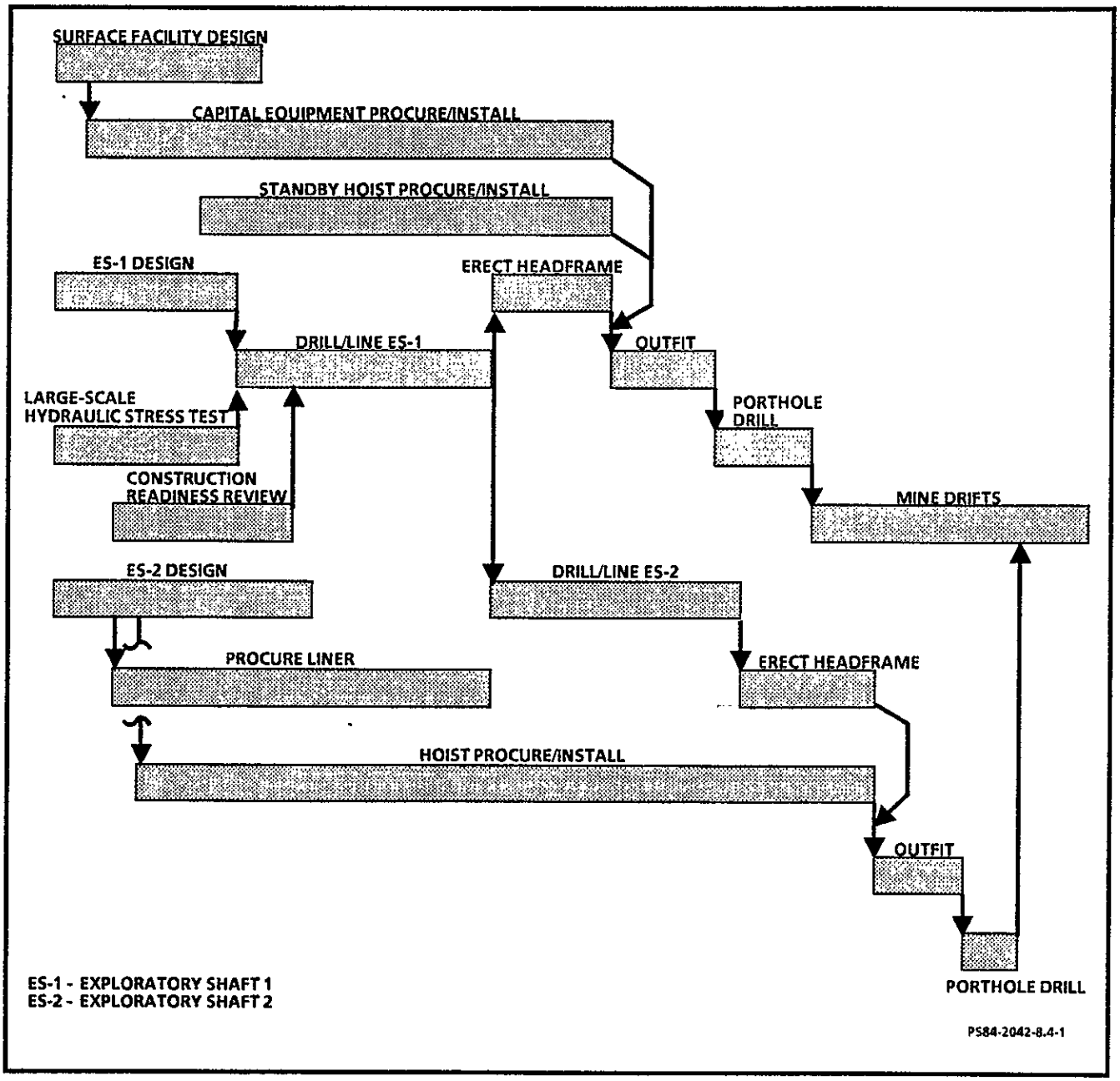

Figure 8.4-7. Exploratory Shaft Facility construction sequence.

8.4.2.1 Exploratory shaft construction and related testing

The Exploratory Shaft Facility will use two shafts, Exploratory Shaft 1 and Exploratory Shaft 2 (see Fig. 8.4-2). Two shafts are required for adequate ventilation and for worker safety (emergency access or egress). Each shaft will be constructed by the reverse circulation, blind-boring method using a surface drill rig. This construction method was adopted as the one best suited to meet the Exploratory Shaft Facility requirements for the following reasons:

- Highest probability of successful completion.
- Minimum concern for the effects of high-capacity aquifers.
- Minimum zone of disturbed rock thereby minimizing the possibility of leakage of water into the test facility from around the liner.
- Shortest time of construction.
- Safest construction technique, since all human activity will be above ground until the shaft has been completed and lined.

Hydrologic testing via portholes through the shaft casing and testing at the breakout location will proceed after the shaft liner is grouted into place. Successful execution of Exploratory Shaft 1 construction will demonstrate that a shaft can be sunk at the reference repository location and that safe access can be provided to the reference repository location for in situ testing.

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8.4.2.1.1 Exploratory shaft construction

Exploratory Shaft 1 consists of a 2.8-m- (9.2-ft-) diameter hole drilled to a depth of 1,036 m (3,400 ft) and lined with a 1.8-m- (7.2-in.-) ID liner to a depth of 1,024 m (3,360 ft) (Fig. 8.4-8). The diameter of the liner for Exploratory Shaft 2 will be 3.0 to 3.6 m (10 to 12 ft) as discussed in the introduction to this section. However, the method of constructing both shafts will be essentially the same. The discussion that follows, although specifically applicable to Exploratory Shaft 1, also applies to Exploratory Shaft 2, except for the sizes of holes, liners, shaft collar, and related parameters.

The starter hole for Exploratory Shaft 1 has already been constructed by auguring a 4.4-m- (172-in.-) diameter hole to a depth of 32 m (104 ft). Then, a 4-m- (156-in.-) ID, corrugated-steel liner has been installed to depth and cemented into place. Following this liner installation, the 6-m by 6-m by 4-m (20-ft by 20 ft by 13-ft) reinforced-concrete structure (shaft collar) was poured in place to provide support with mounting bolds for the shaft headframe. Next, a reinforced-concrete drill rig pad was poured in place to support the drill rig during the actual shaft drilling and lining operations.

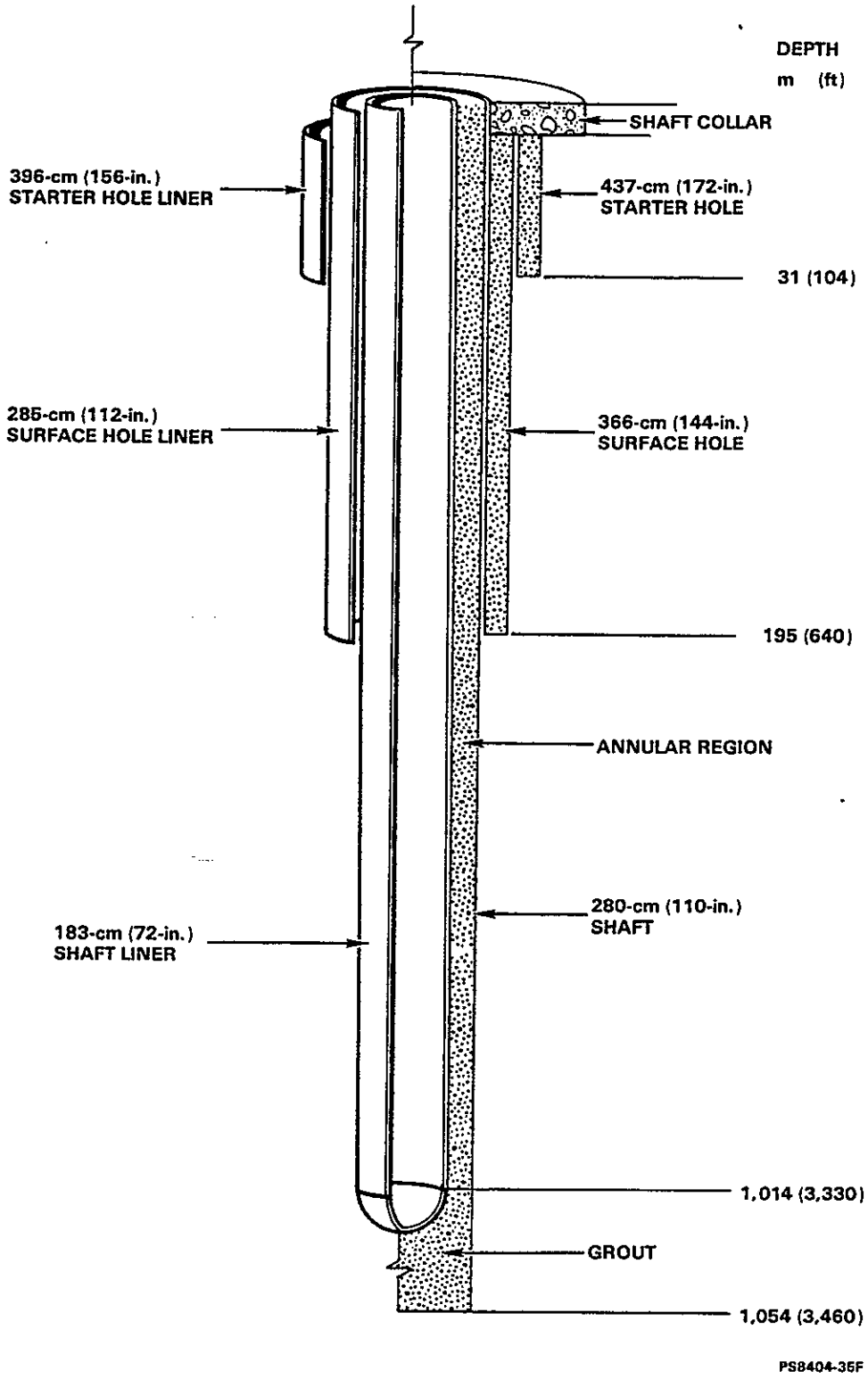

Figure 8.4-8. Drilled shaft concept (RKE/PB, 1984).

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When Exploratory Shaft Facility construction restarts, a 3.7-m (144-in.) surface hole will be drilled to penetrate the overlying sediments that are 184 m (605 ft) thick as determined by borehole RRL-2, which is located 91 m (300 ft) east of the first shaft centerline. The final depth of the surface hole will be field determined and will range between 186 and 195 m (610 and 640 ft) deep. The objective is to penetrate the overburden and a minimum of 1.5 m (5 ft) of the Elephant Mountain Member of the Saddle Mountain Basalt in order to firmly anchor the 2.8-m- (112-in.-) ID surface casing in the uppermost basalt rock. The surface casing will be grouted in place and will serve to support the overburden during the remainder of the drilling operations.

The final hole will be 2.8 m (110 in.) in diameter to a depth of approximately 1,054 m (3,460 ft). The 1.8-m- (72-in.-) ID liner will be installed to a depth of 1,044 m (3,330 ft). The liner weighs in excess of 2,300,000 kg (2,500 tons), which is beyond the lifting capacity of the rig (707,000 kg (780 tons)). To overcome this problem, the liner will be equipped with a hemispherical head welded on the bottom section which will be partially filled with fresh water. This will maintain a small negative buoyancy as the liner is "floated" into place in the mud-filled hole in preparation for the grouting process.

During the drilling, liner installation, and grouting operations, the open hole will remain filled with mud that eventually will be displaced during the final grouting of the 1.8-m (72-in.) liner. Mud is circulated to remove the cuttings from the bit face and transport them to the surface for disposal during drilling. The mud also serves other functions: it stabilizes the rock walls by hydrostatic pressure, minimizes fresh (formation) water inflows, minimizes lost circulation, and cools the drilling assembly during the drilling operations.

The drill mud circulation system is known as an air-assist, reverse-circulation method (Fig. 8.4-9). Fluid flows from the mud pits by gravity to the drill hole, down the annulus between the drilling assembly and hole wall, across the face of the drill bit to the center hole in the bit, and through the hollow drill pipe back to the surface. Compressed air is injected into the drill pipe through an air line that is extended to depths between 107 to 122 m (350 to 400 ft) below the surface. This creates a hydrostatic imbalance between the fluid column in the drill pipe and the column in the annulus and results in the upward flow of fluid through the pipe. Through the circulation of the mud, the rock cuttings (chips) are transported to the surface. The circulation system has been tested at a flow rate of 15,140 L/min (4,000 gal/min).

Once the 1.8-m (72-in.) liner has been "floated" into its final position the process of providing a seal between the outside of the liner and the inside of the drilled hole will begin. This seal, a combination of grouting and chemical seal rings, will be designed to prevent groundwater from entering the subsurface excavations. As shown in Figure 8.4-10, the liner is fitted with slotted pipe as guides for grouting supply lines. Grout lines will be inserted into these line guides and lowered to near the bottom of the drilled hole (Fig. 8.4-11).

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9 2 1 2 3 5 5 1 0 3 3

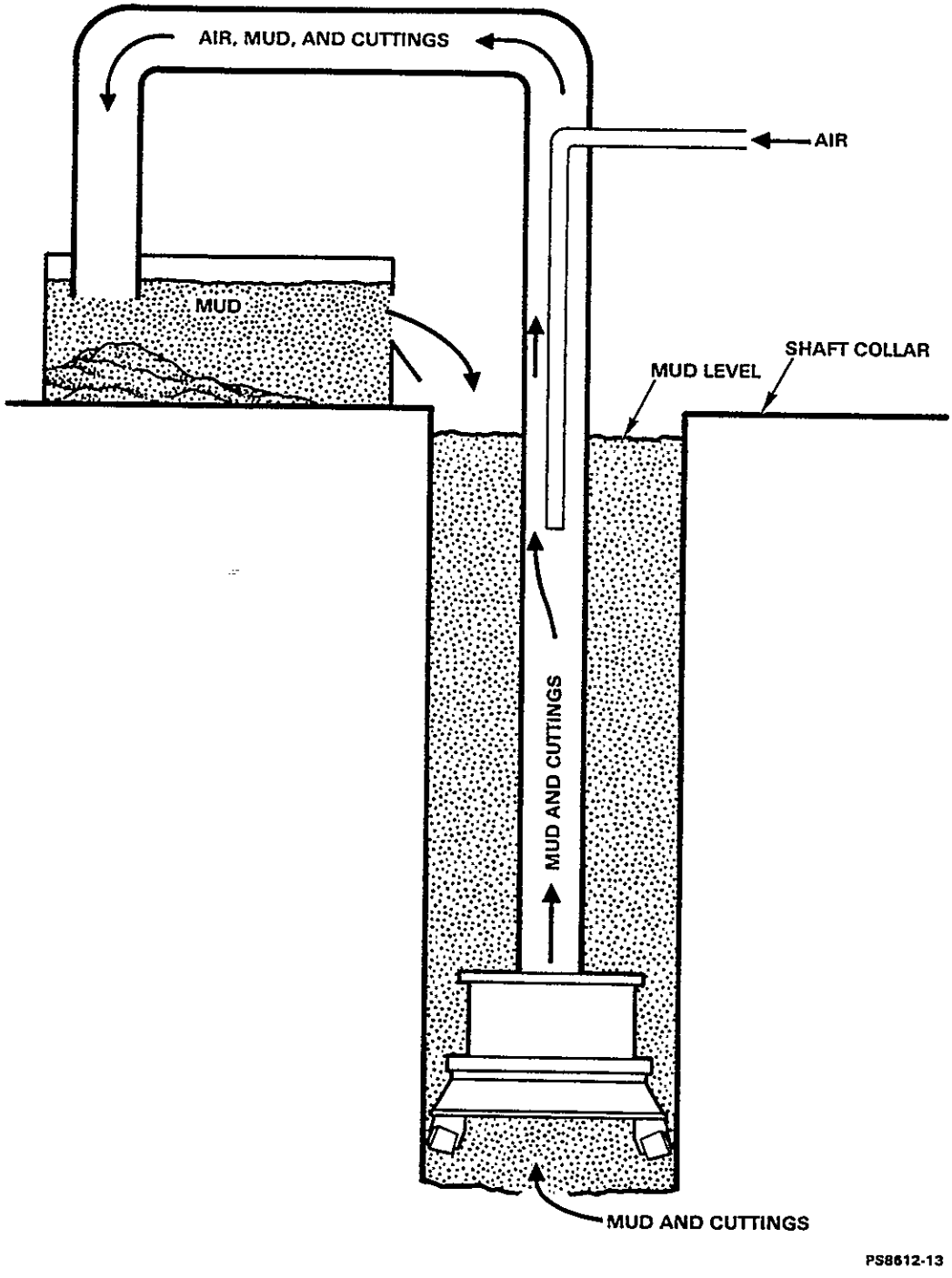

Figure 8.4-9. Drilling methodology.

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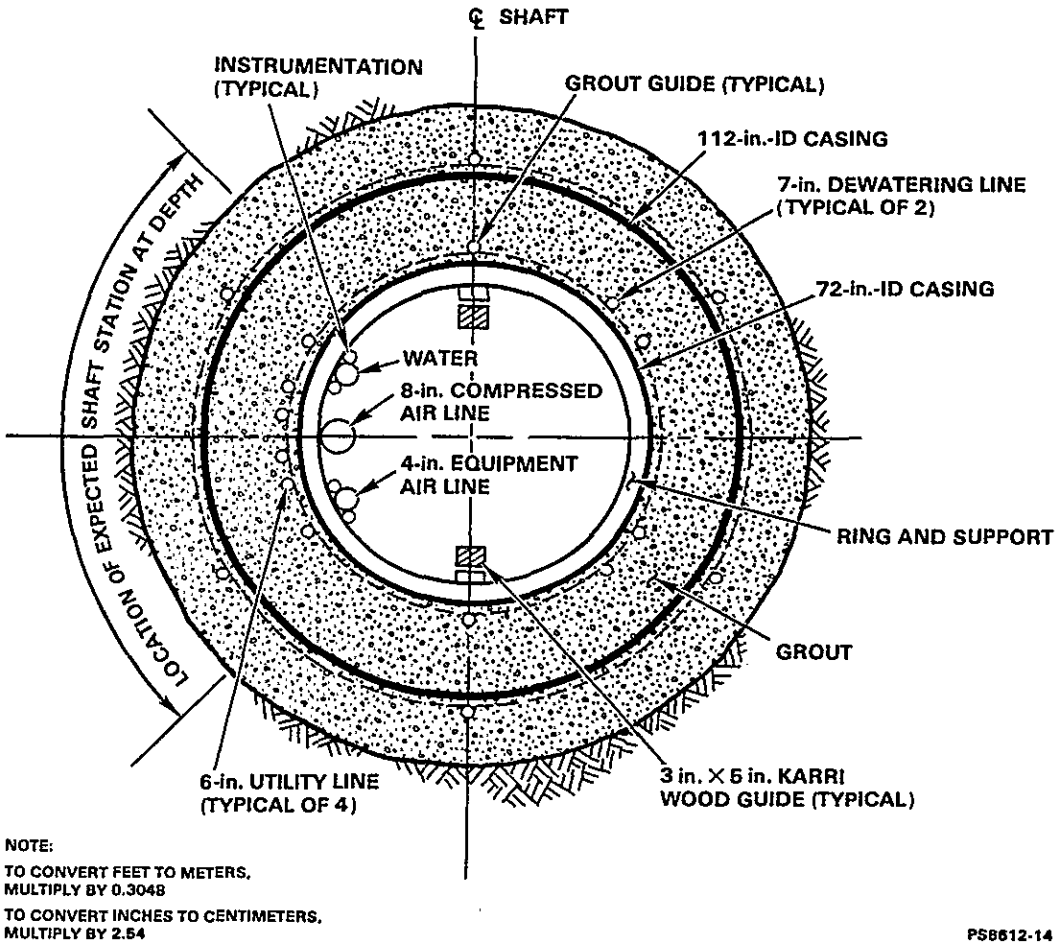

Figure 8.4-10. Typical exploratory shaft cross section.

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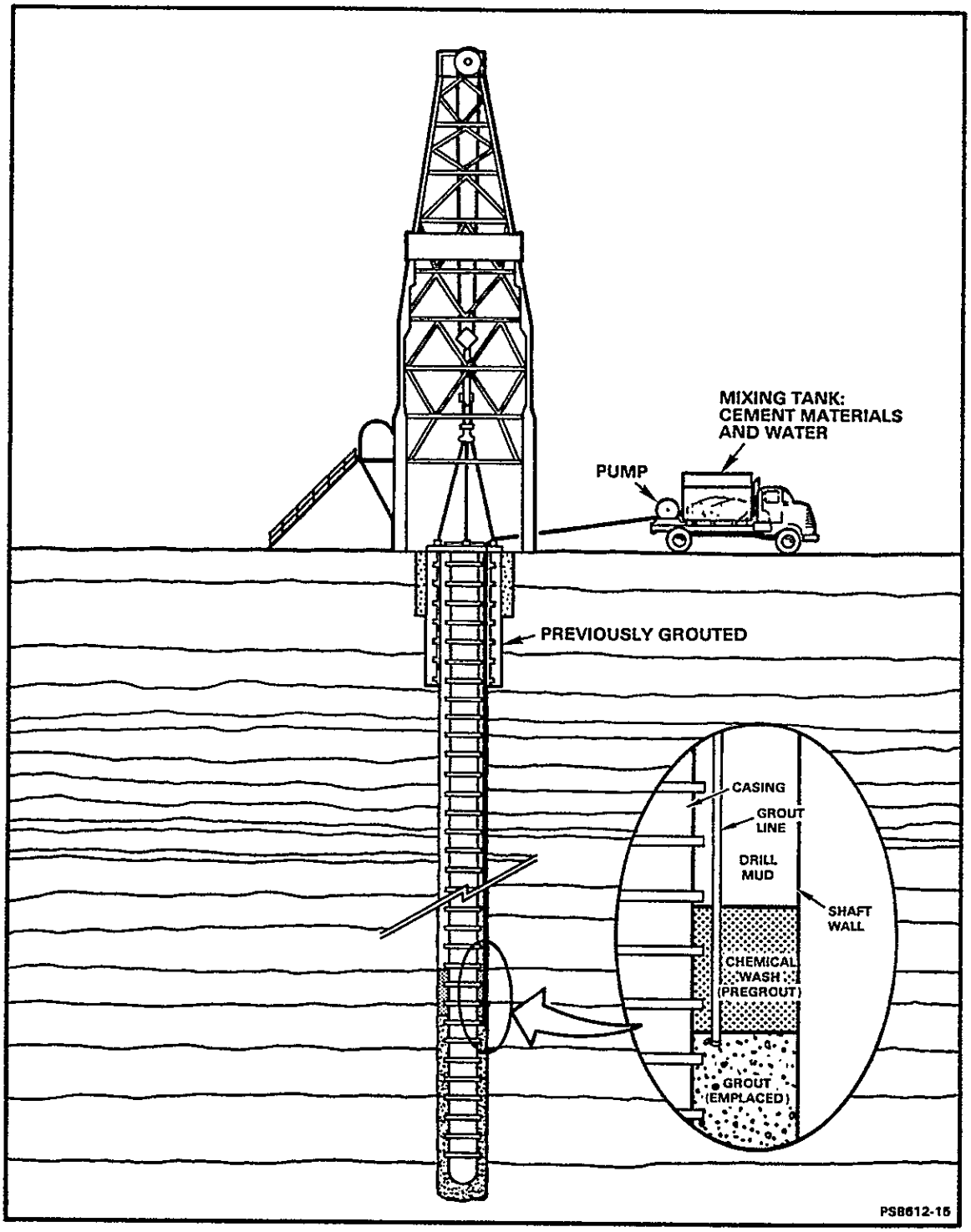

Figure 8.4-11. Exploratory shaft grouting technique.

When the grout lines are in place, the drilling mud in the hole will be thoroughly circulated by pumping mud through the grout lines, followed by a mud removal wash and water. This process will aid in the removal of the mud in the area to be grouted. Grout, made of water and cement and formulated to avoid shrinkage when set, will be pumped into the hole to anchor the bottom of the liner. After the initial stage has been placed, grout lines will be removed from the grout and thoroughly flushed with water.

After the first stage of grout has taken its initial set, the grout lines will be lowered to the top of the first stage and grout will be pumped into the annular space between the liner and the rock wall. This process will be continued until the grout is at the bottom of the first interval selected for chemical seal ring placement, presently planned to be below the shaft breakout level (Fig. 8.2-12). Grout placement will be monitored by in-process logging from inside the liner wall. This value will be converted into a volume using values obtained from drilled-hole logging conducted prior to liner installation. This volume will then be compared with the volume used to check for abnormal losses of grout.

A chemical seal ring is an organic polymer material placed in the hole-liner annulus to provide additional assurance that water will not enter the subsurface areas from aquifers. The chemical seal ring material will be mixed and placed as a pumpable slurry using grouting equipment. After being placed, the slurry changes chemically to form an insoluble elastic solid that swells as it absorbs any water that may be present. The swelling serves to seal the annulus area.

A small quantity of a short half-life radioactive marker with a half-life of less than 10 d may be added to the chemical seal ring as it is being placed. The top of the ring can then be accurately determined by a logging tool. This technique is consistent with standard industry practice.

After the chemical seal ring has had sufficient time to take its set, the grouting process, as described previously, will resume until the next chemical seal ring interval is reached. The sequence of seal ring placement previously described will be repeated. After this second seal ring is placed, routing is presently planned to be continued up to the ground surface.

As part of the liner installation, four ventilation lines and two dewatering pipes will be mounted on the outside of the casing (see Fig. 8.4-10). These lines will be closed during installation of the casing and will be opened when the shaft bottom is accessed.

The remainder of the shaft outfitting services will be installed inside the casing. These systems include the cage and guides, an additional ventilation line, an equipment air line, a water line, and electrical and communication cabling. Prior to breakout, the service lines will be terminated with shutoff valves above the breakout horizon.

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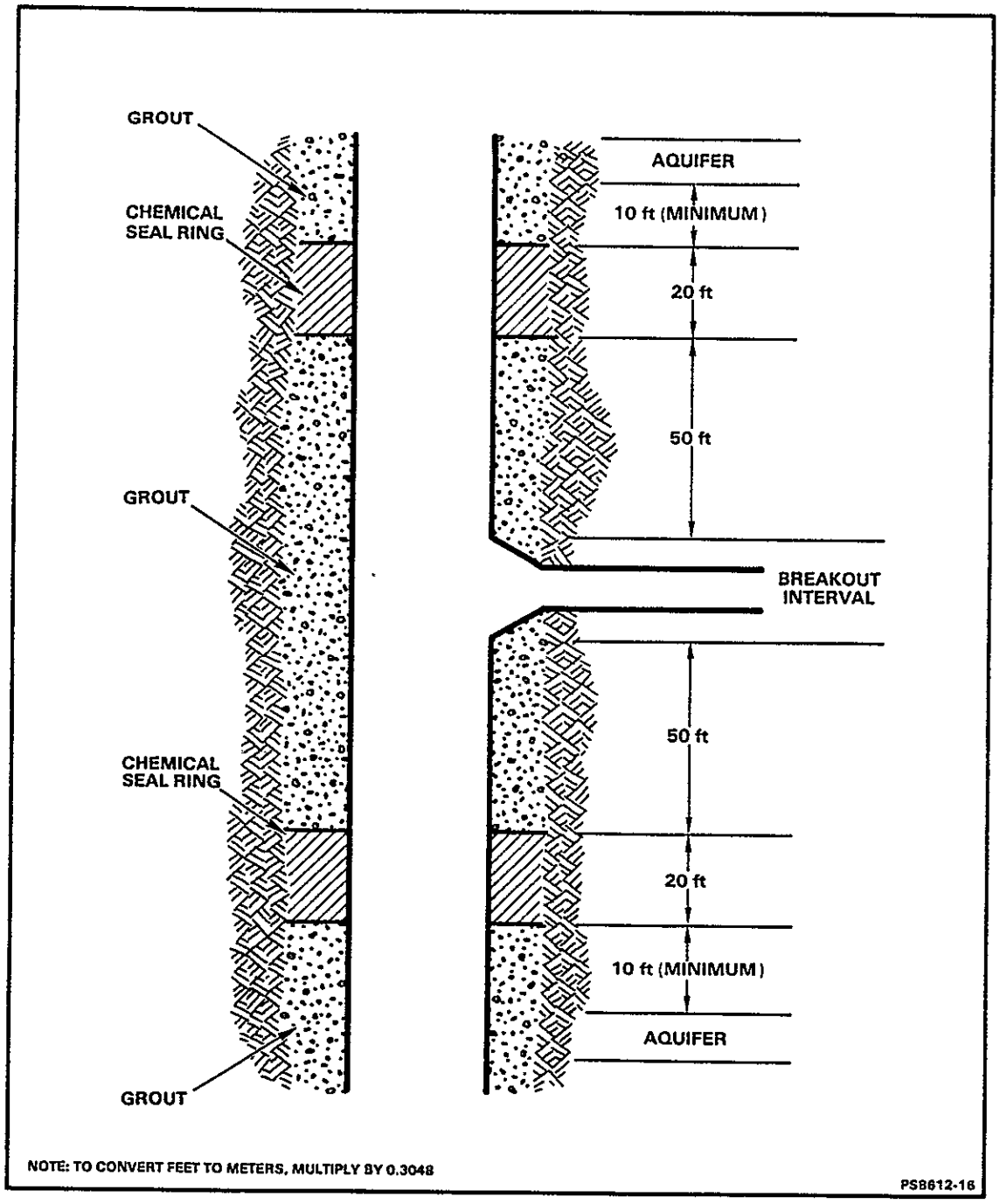

Figure 8.4-12. Chemical seal ring placement.

8.4.2.1.2 Exploratory shaft services development

The shaft services include hoisting and conveyance systems, ventilation system, dewatering system, service air and water systems, electrical power systems, and communication systems. Services for the entire underground facility (after the shafts are connected) are discussed in Section 8.4.2.2.2

8.4.2.1.2.1 Hoisting and conveyance systems

The headframe will be braced, bolted, steel structure that will be erected above the first shaft. Its main function will be to support the headsheaves required for movement of shaft conveyances. The structure will be designed to support the hoist rope (cable) and conveyance loads and to accommodate operation and maintenance access as required. It will also be designed and constructed to withstand credible natural events, such as earthquakes and windstorms. The headframe will have features designed into it for discharging broken rock from subsurface excavations.

The main hoist will be a single drum, direct current-powered hoist capable of moving workers and materials within the shaft. In the first shaft (Exploratory Shaft 1), the hoist will be equipped with a cage for transporting personnel, equipment, and materials and will be fitted with a skip for mucking (removal and transporting or broken rock). There is no permanent skip arrangement presently planned for hoisting muck in Exploratory Shaft 2).

Emergency access for rescue and (or) repairs is possible using a standby cage operating on an independent hoist system and standby electrical power. The standby cage is stored at ground level inside the framework of the headframe. The standby rope is permanently rigged and held out of the regular operation right-of-way until its use becomes necessary. The system is designed to operate with a surface mounted, single-drum hoist in an unbalanced mode. On completion of the main drift in the underground facility, the Exploratory Shaft 2 conveyance can also be used in emergency situations.

8.4.2.1.2.2 Ventilation system

The ventilation system filters, compresses, cools, and delivers outside air to the subsurface working faces. Air from the subsurface workings is exhausted through the shaft to the atmosphere.

Equipment for filtering, compressing, and cooling the ventilation air will be located at ground level in the hoist house. This equipment will consist of three air compressors, two chiller-dryers, distribution piping, controls, and instrumentation. The distribution piping will be installed below grade from the hoist house to the shaft collar. From the shaft collar, the piping will extend underground in the four designated air supply pipes on the outside of the shaft casing (see Fig. 8.4-10).

Two air compressors and one chiller will normally operate to supply air to the farthest workings at the conditions specified in RKE/PB (1984; 1986). Distribution piping will deliver the compressed ventilation air from the chiller-dryer to the subsurface. Distribution piping will consist of a supply main, four supply lines attached to the exterior of the shaft casing, air silencers for the shaft and breakout drift development, and interconnecting piping and valves. At the breakout horizon, the four supply pipes will be directed into the shaft station, terminating the air silencers.

A 203-mm (8-in.) ventilation pipe will be provided inside the shaft for use during shaft outfitting and breakout work until the four pipes can be accessed and the ventilation system made operations. During later stages, this pipe will serve as the standby (emergency) ventilation.

The standby ventilation system is designed to provide cooled air to the subsurface, independent from the normal underground ventilation system. Standby ventilation equipment is located in the standby hoist house and powered by either normal power or the standby diesel generator. Standby airflow is supplied by a separate air compressor and chiller-dryer through a single distribution line to the subsurface. The air may be routed down the shaft through either the four 178-mm (7-in.) pipes or the standby 203-mm (8-in.) pipe. The emergency ventilation system is connected to the normal ventilation distribution network at the shaft station.

8.4.2.1.2.3 Dewatering system

Each shaft will have its own dewatering system that will pump all drainage water from the bottom of each exploratory shaft. Deep-well pumps for each shaft will lift the water to the surface, via a piping system, for disposal by environmentally acceptable methods. The pumps will be sized to remove a 3-m (10-ft) collected head of water in the shaft in approximately 10 min (750 L/min (200 gal/min)). The maximum estimated water usage includes water from tools and equipment and will be substantially lower than the capacity of the dewatering pumps. Also, any leakage from the grouted areas, whether at the shaft station breakout or through a porthole at elevations near the breakout, will be included within the pump capacity. A contact with the nearest aquifer through a fault or other previous geologic structure was included in determining the pump capacity.

8.4.2.1.2.4 Service air system

Service air will be supplied from equipment air compressors in the hoist house to the shaft through a 102-mm (4-in.) pipe. Outlets will be provided where necessary within each shaft to support operations and testing. Equipment air is provided by two air compressors, each capable of supplying the maximum expected demand to the subsurface--0.28 m^3/s (600 ft^3/min). The second unit operates alternately with the first unit when the latter is out of service.

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8.4.2.1.2.5 Service water system

A water line for operation of underground mining (machinery and dust suppression) is provided. It has manual and automatic shutoffs. The line is located inside the shaft casing so that it may be inspected and water leaks may be stopped. It is fitted with pressure reducers to avoid excessive hydrostatic pressure at the shaft bottom. Outlets are provided where necessary within each shaft to support operations and testing.

8.4.2.1.2.6 Electrical power system

Power for the monitoring equipment, dewatering pumps, and other necessary mine services is supplied from the surface to the underground station via power cables located inside the casing. All necessary remote controls and monitoring instruments are located in a dedicated area of the Exploratory Shaft 1 hoist house on the surface. Standby power features are described in Section 8.4.1.2.3.

8.4.2.1.2.7 Communication system

Communication lines are provided from the shaft to the hoise house so that information on conditions, both surface and underground, can be exchanged rapidly. All instrumentation and data lines are installed inside the shaft casing, including data acquisition cables for porthole and breakout testing. Additional features of the communication system are described in Section 8.4.1.2.4.

8.4.2.1.3 Porthole testing

Portholes are provided within each exploratory shaft casing to allow borehole drilling through the casing and surrounding grout into the host rock at predetermined locations. The locations are specified in meet the following objectives (further description can be found in Section 8.3.1.3.4.3.2):

- Assess the hydraulic conductivity at the preferred horizon (Cohassett flow) primarily for safety of mine personnel during breakout.
- Confirm surface borehole hydrologic test data.
- Assess hydraulic conductivity of other flow interiors and flow tops.
- Evaluate the shaft liner seals and the disturbed rock zone.

The portholes are double-plugged, mechanical fittings in a reinforced area of the casing. A back-flow preventer assembly will be attached to the inner port before removal of the outer plug and drilling of boreholes. In this way, the casing penetration is always sealed and under control. This is a safety feature that will control groundwater inflow into the shaft should a water-bearing layer be tapped. Boreholes are sized to allow access for hydrologic testing.

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Prior to emplacement of the shaft casing, portholes will be installed in the casing at depths selected from data from the principal borehole (RRL-2). Testing will occur in both Exploratory Shaft 1 and Exploratory Shaft 2. Two portholes will be installed in the liner at each test level. All porthole drilling and testing will be conducted from a work platform specifically designed for these activities. Test holes will extent laterally, with some inclined, from 12 to 40 m (40 to 130 ft). All boreholes will be continuously cored and monitored for grout seal, drilling rate, observable water inflow, and changes in drilling conditions. Porthole testing instrumentation will be connected to the data acquisition system, which has features described in Sections 8.4.2.2.2 and 8.4.2.2.3.

8.4.2.1.4 Shaft station construction

Successful completion of shaft breakout and initial subsurface development at the shaft station will confirm the following objectives:

- Verification that an exploratory shaft can successfully seal off the groundwater system.
- Verification of acceptable drift construction methods that could be used on a future repository.
- Demonstration of acceptable and safely supported subsurface openings capable of extension into the preferred horizon.

Shaft station construction includes the following operations:

- Shaft preparation, including modifications to shaft furnishings to preclude damage during breakout activities.
- Installation of a temporary horizontal bulkhead below the shaft station level to collect broken rock.
- Drilling pilot holes at the shaft breakout horizon.
- Breaking through the shaft casing and grout.
- Developing a shaft station and drift by smooth-wall drilling and blasting techniques and by concurrently installing ground support.
- Equipping and furnishing the shaft station.
- Cleaning up and reinstalling shaft services and utilities.

The shaft will be fully equipped with conveyance hoisting, ventilation, and other services prior to shaft breakout. It will be necessary to prepare and shaft against damage to the shaft utilities from the breakout activities.

Shaft preparation work will involve removing permanent services within the shaft casing to a point above the breakout horizon, providing for temporary services below this point, and protecting or removing shaft guides during development blasting at the breakout horizon.

A horizontal bulkhead or platform will be constructed below the shaft breakout to prevent fly rock and rock spillage during blasting and skip loading from dropping to the bottom of the shaft potentially damaging the dewatering pumps. The bulkhead will be designed to withstand blasting concussion and the weight of the rock arrested by it.

Before breaching the casing, it will be necessary to drill several deep pilot holes in the direction of the subsurface development to test for water and to ensure the integrity of the rock strata and grout bonding. Although flooding is not expected to be a problem, backflow preventers will be used to protect personnel by withstanding any potential inflow of water where the casing is penetrated during porthole drilling.

The breakout opening at the shaft lining will be designed to be of the minimum working dimensions required to permit access to the shaft conveyance, shaft services, and skip loading. The casing will be cut and removed, and the grout will be broken away mechanically to the design dimensions with minimum damage to the lining. The casing will be breached over a 165-cm (65-in.) width, corresponding to an arc of 130° at the shaft axis and a height of 381 cm (150 in.) (see Fig. 8.4-6, Detail "H-H").

The shaft station and drift development will be accomplished by conventional drilling and blasting, using smooth-wall techniques; the opening shape and size will be designed to permit adequate rock support, installation of services, and operation of development equipment. Blasting techniques will be designed to minimize fly rock damage and overbreak. To ensure worker safety, adequate support and protection from rockfalls from rock relaxation will be provided, and the station will be equipped with services and other equipment necessary for the underground test facility construction phase.

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8.4.2.2 Underground test facility construction and testing

The underground test facility will be constructed to provide access to the host rock at the selected repository horizon and in situ testing purposes. This section describes the construction and development of facilities and services necessary to support the in situ testing planned in Sections 8.3.1.2, 8.3.1.3, and 8.3.2.2.

8.4.2.2.1 Underground test facility construction

The Exploratory Shaft Facility will provide access to the repository horizon to perform the necessary tests to characterize the host rock medium. Because this characterization process depends on direct access to the host rock medium, a finite amount of excavation must be performed to provide space for testing and to provide the necessary facilities to support underground operations. The following considerations are necessary to complete the design of the subsurface excavations:

- Determination of the subsurface layout to be developed.
- Methods of underground excavation and ground support.
- Provision of hoisting systems for the layout.
- Provision of areas in the layout for supporting work and equipment.
- Description of measures required to ensure personnel safety.

  Provision for necessary maintenance.
- Provision of flexibility in the layout to address potential future expansion requirements.

8.4.2.2.1.1 Subsurface layout

In developing the conceptual design of the subsurface layout described in this section and shown in Figure 8.4-5, a number of alternative layouts were evaluated. The various layouts were evaluated for requirements such as safety, flexibility for expansion, and ease of construction and access. The selected underground layout has been designed to accommodate test requirements discussed in Section 8.3. The final test design requirements are presently being developed. These requirements will be incorporated into the definitive design for the facility and could potentially modify the existing subsurface layout.

The underground test facility (see Fig. 8.4-5) for the Exploratory Shaft Facility will consist of two drilled vertical shafts (Exploratory Shaft 1 and Exploratory Shaft 2) with shaft stations located in the Cohassett flow, interconnecting access drifts and underground testing and support areas including lunchroom, first aid station, offices, shop, storage area, pump stations, sumps, and electrical load centers. A description of shaft construction and lining is presented in Section 8.4.2.1. At the candidate repository horizon, a shaft station, 4 m by 2.7 m by 16.5 m (13 ft by 9 ft by 53 ft), will be constructed at each shaft. A main drift, 4 m by 2.7 m (13 ft by 9 ft), will connect the two shaft stations; this drift is enlarged locally to 7 m by 3 m (23 ft by 10 ft) to accommodate the first aid station, motor control centers, pump station, sump, an office on the north end, and the shop and warehouse on the south end.

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Other features to be provided include the following (see Fig. 8.4-5 and 8.4-6):

- Hydrology drift consisting of the cluster heater drift, 7 m by 3 m (23 ft by 10 ft); the chamber access drift, 4 m by 2.7 m (13 ft by 9 ft); the transition section; and the chamber drift, 4.6 m by 4.6 m (15 ft by 15 ft).

- Rock mechanics drifts 1 and 2, 4 m by 2.7 m (13 ft by 9 ft) and 4.6 m by 4.6 m (15 ft by 15 ft), respectively.

- Second exist drift, 2.4 m by 2.4 m (8 ft by 8 ft), enlarged at the ends to 4.6 m by 3 m (15 ft by 10 ft) and 4.6 m by 4.6 m (15 ft by 15 ft) to accommodate proposed testing.

- Mine-by drift, 7.7 m by 3.3 m (25 ft by 11 ft).

- Observation galleries, overhead and lateral, 4 m by 2.7 m (13 ft by 9 ft) and 4.6 m by 3.3 m (15 ft by 11 ft), and access raises, 1.8. m (6 ft) in diameter.

The hydrology drift extends west from Exploratory Shaft 1 for 170 m (560 ft) with varying cross sections. Rock mechanics drift 1 is 56 m (184 ft) south of, and parallel to, the hydrology drift, which runs west for 50 m (164 ft) from its intersection with the main drift. Rock mechanics drift 2 is perpendicular to rock mechanics drift 1 and extends 39 m (130 ft) south from its intersection with the west end of rock mechanics drift 1. The second exit drift (56 m (184 ft) long), which connects the hydrology drift and rock mechanics drift 1, is 35 m (114 ft) west of, and parallel to, the main drift.

The mine-by drift (46 m (150 ft) long) is 18 m (60 ft) south of, and parallel to, rock mechanics drift 1 and connects the main drift and rock mechanics drift 2. The overhead observation gallery is 16.7 m (55 ft) above, and parallel to, the mine-by drift and is accessed from both the main drift and rock mechanics drift 2 by raises. The lateral observation gallery is 16.7 m (55 ft) south of, and parallel to, the mine-by drift and connects the main drift and rock mechanics drift 2.

8.4.2.2.1.2 Underground excavation and ground support

Initial excavation will be carried out through Exploratory Shaft 1. All personnel, materials, utilities, and equipment will enter the subsurface areas via the first shaft. The hoisting capabilities of one shaft will define limits to the number of personnel underground and to scheduling of materials moved underground. Ventilation during the period will be supplied through compressed air lines installed on the outside of the shaft casing during construction. Chilled compressed air (10 °C at 345 kPa (50 °F at 50 lbf/in^2 gage)) will move through the air lines at a rate of 340 m^3/min (12,000 ft^3/min) and be distributed through the working areas. Exhaust ventilation air will flow up the shaft to the surface.

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Three methods of blast-hole drilling are presently planned to be used during the excavation of the Exploratory Shaft Facility layout. The first method, featuring pneumatic jacklegs (drilling), is used during early development while compressed air ventilation is in effect, and before the two shafts are connected. The second method, featuring pneumatic two-boom jumbo drills will be used to develop all remaining headings prior to interconnection of the two shafts. The third method, featuring hydraulic, electric multiple-boom jumbo drills and supporting electric equipment, is used from the time flowthrough ventilation is in place until the end of subsurface development. This latter method cannot be used until flow through ventilation is established because the equipment generates more heat than can be handled by the compressed air system.

Smooth-wall blasting has been selected to minimize the extent of the disturbed rock zone. A typical sequence of events that would be required to advance a drift face using smooth-wall blasting by both the jackleg and jumbo drilling methods follows:

- Advance probe holes to determine rock and hydrologic conditions in the direction of planned development.
- Drill the face shothole pattern, load the shotholes with explosives, and protect terminus of all temporary services.
- Shut down the ventilation system.
- Fire the explosive round from the surface.
- Clear blasting fumes by restarting ventilation system.
- Bar down (remove loose wall and back rock) prior to removal of blasted rock.
- Place preliminary rock support as required.
- Examine the rock conditions including those of the newly created opening (mapping).
- Remove and haul blasted rock (muck) to the Exploratory Shaft 1 for hoisting to the surface.
- Refine the drift cross section as necessary to meet minimum clearance criteria.
- Complete rock support requirements.
- Advance the temporary services in support of development (ducting, compressed air, service water, power, and communications).
- Advance the survey and control points, and mark the face for the next round.

- Install the basis support systems for permanent utility and electrical requirements simultaneously with temporary services.
- Clean up recently advanced area, and prepare new face for drilling.
- Repeat cycle.

The construction schedule is shown in Figure 8.4-7. Delays for various test activities to be done during construction are imposed on the standard sequence of events previously mentioned. These test activities include probe-hole drilling, instrumentation holes, overcoring holes, and acoustic emissions stations. Allowances for these tests are included in the schedule.

An ongoing program of probe-hole drilling will be performed to detect abnormal geologic, hydrologic, or structural features in or near the expected heading (drift) path. A cone-shaped pattern of probe holes is proposed to be drilled ahead of the drift face, a distance equivalent to a 3-wk (approximately 40 m (150 ft)) advance in the drift being developed. These holes are drilled so that a 30% probe-hole pattern overlap interval is always maintained. A proposed probe-hole pattern, its expected overlap, and advance cycle are shown in Figure 8.4-13. Each probe hole will be collared (started) in the drift face, then a standpipe and packer will be installed, and the hole advanced to its full depth. The standpipe and packer assembly should be capable of resisting the pressure of a full hydrostatic head when in place. Additionally, a blowout preventer is attached to each packer.

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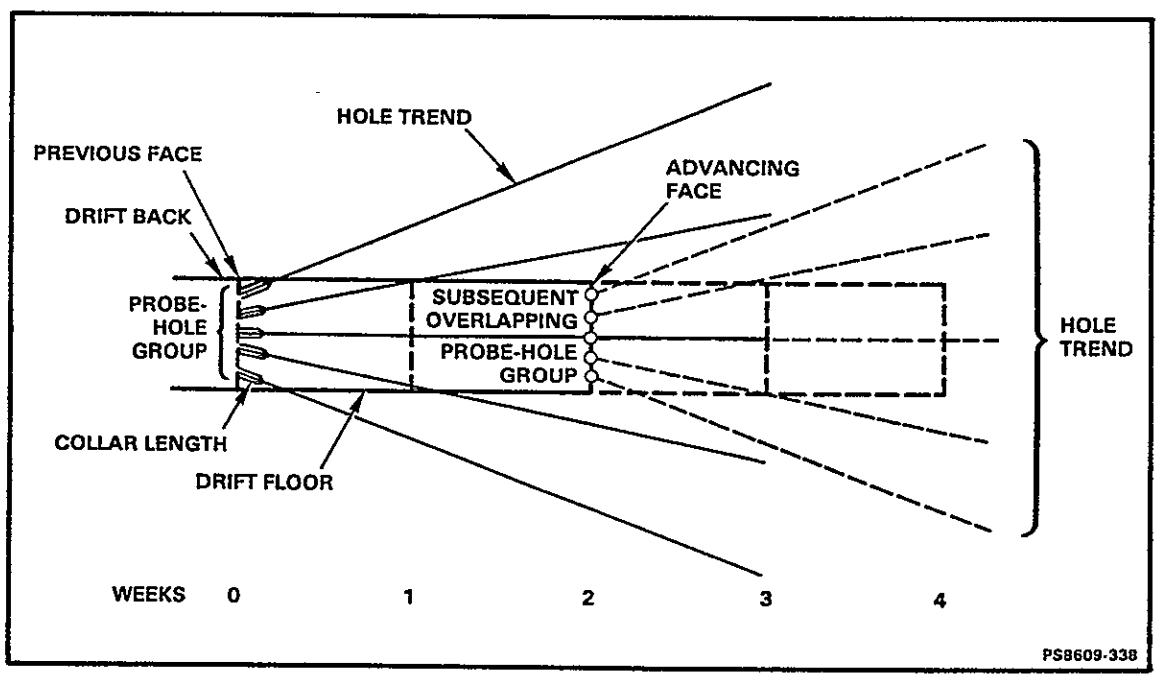

Figure 8.4-13. Probe-hole method of drift advance.

Permanent services, utilities and electrical, will be installed at a distance behind the advancing drift face sufficient to ensure protection from blasting and any other effects of general drift development.

Initially, blast-hole drilling will be done using hand-held jackleg drilling machines until the larger capabilities of a flowthrough ventilation system are available to support higher production. Until such time, the wider layout sections, pump station, and initial hydrology drift are developed by advancing a nominal 4-m- (13-ft-) wide by 2.7-m- (9-ft-) high pilot heading and then slashing out (widening) the drift to the full required dimension. A round can be drilled in one shift with blasting occurring at the end of the shift when all personnel are on the surface.

On the second shift, pneumatically powered, load-haul dump units will transport the broken rock from the active heading to the Exploratory Shaft 1 shaft station. At the station, the muck is dumped into the skip. Much hoisting is described later in this section.

By proper scheduling of the jackleg drilling and mucking cycles between headings, an operation on two headings can be maintained even with the limited number of personnel allowed before the two shafts are connected. A 6.5-d work week is planned. The remaining time each week will be used to maintain the hoist and other mechanical systems as necessary.

As can be seen from Figure 8.4-7, main drift excavation will be under way while the second shaft is being outfitted. Main drift excavation will be coordinated with Exploratory Shaft 2 porthole drilling in the vicinity of the shaft station such that an adequate shaft pillar remains until porthole testing has been completed. Main drift excavation will then resume using probe-hole drilling and the drill-blast-much sequence previously described until the drift face is within approximately 5 m (16 ft) of the Exploratory Shaft 2 liner. The remainder of the rock and the grout will be removed mechanically (without blasting). The liner itself will then be cut from the inside of the shaft.

After the two shafts are connected and the flowthrough ventilation system is established, the development method will convert to the use of two-boom jumbo drills and electrical load-haul dump equipment. All remaining drifts will be driven full size with up to three active headings being developed simultaneously. Otherwise, the sequence of events in the development cycle would remain as stated above.

Drifts are envisioned to be stabilized using a standard rock reinforcement pattern. The basis pattern consists of 2.4-m- (8-ft-) long rock dowels, fully encapsulated and installed in a rectangular pattern on 1.8-m (6-ft) centers. The rock dowels are deformed steel rods (rebars), 25.4-mm- (1-in.-) diameter, Grade 60 steel. The encapsulation medium (cement or epoxy) will be determined after additional testing. Other types of rock bolts are also being investigated for site characterization use.

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The rock reinforcement will be initiated after each round of reentry after blasting and completion of scaling. Localized zones of incompetent rock that require additional reinforcement will be stabilized using a variation of the basic pattern. Additionally, wire mesh will be installed, as needed, to eliminate the possibility of rockfall while maintaining access to the rock surface.

If additional reinforcement is still indicated, welded-wire-reinforced shotcrete can be applied. The shotcrete would be applied in at least three layers. Prior to shotcreting, geologic mapping and required geomechanical testing will be completed.

8.4.2.2.1.3 Hoisting systems

The hoisting systems described in Section 8.4.2.1.2.1 will also be used to support the Exploratory Shaft Facility layout. The hoist system in the first exploratory shaft will be used to transport men (up to 6) and materials, inspect the shaft, and hoist muck during layout development. The hoist system in the second exploratory shaft will allow shaft inspection, personnel egress and ingress at shift change (up to 24), and standby personnel hoisting in an emergency.

Each of the two shafts has a different, though slightly overlapping, hoisting duty. In the conceptual design, the Exploratory Shaft 1 system is the more active of the two because of its early availability for development work and later support of testing. The Exploratory Shaft 2 system is available as a second route of access and egress (in addition to the Exploratory Shaft 1 system). With the ongoing evaluation of the second shaft diameter, the functions of each of the shafts will be examined and could change.

During testing operations, the Exploratory Shaft 1 hoisting system serves basically as transportation for personnel and supplies and, secondarily, as a rock hoisting system for the mine-by test.

8.4.2.2.1.4 Operational support areas

The areas used for operational support will vary in size and complexity depending on the needs during the various phases of excavation and testing. During early development, temporary support areas will be provided. During the latter part of development and testing, fully equipped areas will support personnel, equipment maintenance, pumping, utilities, and electrical services.

Shortly after beginning the Exploratory Shaft 2 shaft excavation, an interim sump will be developed in a cutout along the main drift advance. Simultaneously, an initial segment of the hydrology drift will be opened up to provide space for the assembly of development equipment to be used after flowthrough ventilation is established. With the initiation of flowthrough ventilation, the pump station adjacent to the main drift will be activated. This station will have been constructed and equipped during earlier development. The pump station will include two complete sumps and weir sections long with pumps, piping, and overdecking.

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Covers above the entire length of the two sumps and over each of the weir sections are envisioned to minimize moisture transpiration from any collected water to the ventilation air. Major sources of collected water will be dust suppression and equipment usage (e.g., drilling equipment). Additionally, the sump will be vented to prevent the possible buildup of methane gas, if any is detected. The effects of the possible presence of any methane gas are considered in Section 8.4.2.2.2.

The two dewatering pumps, high-voltage motor-control center, facility office, and first aid station are located on a slab over the main sump. The office and first aid station are enclosed by concrete block walls. One wall of the first aid station is backed by the motor-control center.

Piping connections will be provided from each of the sumps to both of the pumps and then to the surface return line, with valving as required.

Following break-in from Exploratory Shaft 2 and establishment of flow in through ventilation, excavation will be begun for the shop and warehouse area. This area will be beside the main drift and near the Exploratory Shaft 2 station. When necessary excavation has been completed, a concrete floor slab will be poured and walls will be erected to separate the warehouse from the shop area. The warehouse area will have a minimum of space for the immediate stocking of equipment, consumables, and testing supplies. Such items include lubricants, small tools, recording supplies, and spare parts. The shop area will contain benches, lockers, and maintenance equipment to accommodate the type of work to be done and the size of mining machinery involved. Only limited repair will be done on the surface. Also, large equipment components will be reduced to manageable size and hoisted to the surface for repair. At the east end of the hydrology drift, near the Exploratory Shaft 1 station, a personnel, electrical, and utility support area will be constructed after the flow in through ventilation system has been established. A concrete slab will be poured for the needed space, and various dividers will be erected to separate each area. For the lunchroom/rest area, sound-reducing block walls will be erected. The remaining areas will be enclosed by wire mesh to limit access while permitting ventilation of the enclosures. One of these enclosures will house the low-voltage electrical load center, and the other will be used for storage of bottled utility gas (nitrogen).

8.4.2.2.1.5 Personnel safety

The safety and health of the work force is especially emphasized. Worker orientation and training are mandatory to ensure that maximum attention is focused on maintaining a safe and health work place. Hazards to personnel can result from either geologic or operational conditions. Examples of hazards resulting from geologic conditions include groundwater inflow, rockfalls, methane emissions, rich rock temperature, and rock slabbing (spalling) conditions. Such conditions are not expected to seriously affect the Exploratory Shaft Facility personnel or layout since the design and the operating instructions accommodate their potential impacts. The engineered safeguards incorporated in the development and operational procedures are meant to ascertain the existence of such problems and to provide appropriate precautionary or remedial measures to control them.

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Apart from potential problems caused by unexpected geologic anomalies, there are potential serious operational emergencies that could occur. Some of the principal operational problems whose effects will be mitigated are fire, explosion, transportation accidents, power failure, hoist accidents, and shaft accidents. Analysis of safeguards and mitigating measures will be included in the Exploratory Shaft Facility definitive design. All hazards will be evaluated, and their mitigation will be a major design feature of the Exploratory Shaft Facility during construction and testing operations. It is planned to use the Near-Surface Test Facility at Gable Mountain (Hanford Site) for personnel safety training prior to their entry into the Exploratory Shaft Facility.

8.4.2.2.1.6 Maintenance

The maintenance program will be based on protection of personnel and achievement of the desired plant availability over the construction and operating life of the facility. All equipment, facilities, and utilities will be designed in accordance with applicable regulations to ensure safe conditions during maintenance activities. Industrial hazards will be further minimized through the provision of the platforms, guard rails, and ladders that provide safe access during maintenance operations.

System interlocks and guards will be provided to prevent high-voltage-circuit overload, and grounding protection devices will be incorporated in the electrical system wherever required by code to protect maintenance personnel. Qualified and trained operators and maintenance personnel will be used to enhance safety. Immediate maintenance that cannot be accomplished at the work place will be performed in the shop areas. Should maintenance be required that cannot be provided at the subsurface facilities, equipment will be hoisted to the surface for repair.

A sufficient parts inventory will be maintained for high-wear items and components for critical systems to minimize downtime for corrective maintenance. Critical systems will be designed to permit preventive and corrective maintenance, including the use of backup (redundant) equipment. Preventive maintenance includes periodic inspection and servicing (cleaning, lubricating, calibrating, adjusting) of systems and their components to ensure reliable operation.

Consideration will be given in the design phase (constructibility reviews) to the access requirements and plant conditions necessary to accomplish maintenance. Systems will be designed to permit inspection while minimizing potential impacts on normal operations. Instrumentation will be readily accessible for routine inspection and calibration to ensure proper functioning.

The design will permit in-service inspections. In-service inspection will be required for certain systems and components that cannot be withdrawn from operation and must continuously perform their function. The ground-support structures for the exploratory shaft and underground openings are in this category. Ground-support structures will be periodically inspected and

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maintained to ensure stability of the exploratory shaft and underground openings. Monitoring, testing, and maintenance of ground-support structures will be carried out as long as the facility is accessible to people.

The design of the exploratory shaft permits inspection of the liner, the annular grout, and the disturbed rock zone of the hot rock by testing through portholes. Means also are provided to inspect the skip guides, safety dogs, hoist rope, and other shaft conveyance components.

Inspection to detect the need for maintenance in critical systems and components is incorporated into the facility instrumentation, control, and supervisory system designs. Critical systems, such as the hoist (emergency access/exit) and ventilation systems and their components, will be monitored to detect abnormal conditions that could lead to a malfunction of the system or that could seriously reduce its design life. Fire detection, ground support, and other essential safety-surveillance monitoring systems will be inspected and calibrated at regular intervals. Surveillance instrumentation will be carefully maintained to achieve a high degree of reliability. Design will accommodate system monitoring, inspection, calibration, and maintenance.

8.4.2.2.1.7 Flexibility for future expansion

The underground layout will be designed to incorporate the potential for future expansion, should additional requirements be identified. The individual components of the underground layout (the main drift, hydrology drift, rock mechanics drifts, and the second exit drift) have been located to allow for future expansion. The size of the final layout will be constrained by ventilation system capacity (including the effects of the diameters of the two shafts) and other parameters that will be identified during the definitive design stage.

The orientation of the main drift allows for additional drifting along its axis from either end in expectation of future enlargement or connection with other development. The length of the main drift between the expected mine-by entry and the second shaft station is available for additional mine-by testing.

The placement of the hydrology drift allows quick access during early development when storage/laydown support of the drifting operations are critical. At later stages of development and testing, the hydrology drift offers the following expansion possibilities.

- Extension of the drift westward for greater chamber test length and volume.
- Further widening of the initial drift length for additional cluster tests.
- Clear south-wall spacing adjoining a large block of virgin rock for performance of added heater tests.
- Following chamber tests, further facility expansion.

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Each of the two rock mechanics drifts can be expanded, presenting several options. Rock mechanics drift 1 can be extended from its west end or expanded along its length to create added space for probe holes and flat jack and plate jack tests. Rock mechanics drift 2 can be extended from its south end to create added geology and geomechanics test space and to support possible consecutive mine-by drifts.

The second exit, in addition to functioning as a safety access and ventilation route, supports the flat jack testing in rock mechanics drift 1 and the heater test in the hydrology drift. Both of the second-exit, test-support sections can be enlarged to provide additional space if required by future geomechanics study plans.

The additional drift construction described above could continue, if necessary, during the testing stage. However, careful coordination will be exercised to preclude construction activities from interfering with ongoing tests. For example, the present of dust and shock waves/vibrations could render certain instrumentation inoperable.

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8.4.2.2.2 Underground test facility services development

The ventilation system for each stage of the subsurface facility development is described in this section. Also discussed in this section are the electrical systems, compressed air for equipment operations, water supply system, sanitary waste disposal, and dewatering system. In addition, the operational system characteristics will provide useful information and design parameters for the full-scale repository if the site is successfully characterized and chosen.

8.4.2.2.2.1 Ventilation system

The subsurface facility must be ventilated and cooled throughout its entire extent. The ventilation system must perform several functions including provision of a safe and comfortable working environment for personnel underground, removal of blasting fumes and other noxious gases, and control of airborne dust.

The ventilation system must be designed and operated to be compatible with the design bases and applicable Federal and state regulations. The ventilation design criteria are provided in RKE/PB (1984; 1986).

The ventilation system will be constructed in phases as outlined below.

- Initial development through Exploratory Shaft 1 shaft station construction. During this period, the underground facility will be ventilated by compressed air that is piped to the bottom of Exploratory Shaft 1 and ducted to the headings.

- During subsurface development. After the two shafts are connected, a flowthrough system will be used to support the underground activities. An exhaust-type system will be installed with the main fan located near the collar of Exploratory Shaft 2, which will pull air through Exploratory Shaft 1 and the underground areas. Fresh air drawn into the underground facility will be cooled in a cooling plant located on the surface. When the flowthrough system becomes operational, the compressed air system will be relegated to a standby (emergency usage) status.

Small amounts of methane gas, entering the Exploratory Shaft Facility as a dissolved constituent of groundwater, are expected to be encountered (see Section 6.1.2.3.2 and WHC (1988)). Classification and safety standards for methane are provided in 30 CFR 57, Subpart T (MSHA, 1987) for all metal and nonmetal mines. The classification criteria are based on the type of methane occurrence (e.g., continuous or intermittent emission, explosive or nonexplosive mixtures) based on the history of the mine or the geologic area. Since no mine or other subsurface facility exists, determination of a classification for the Exploratory Shaft Facility is not possible prior to its construction. However, as a prudent measure and to comply with DOE (1986b), the Exploratory Shaft Facility will be designed in accordance with Category III safety standards (i.e., a mine in which noncombustible ore is extracted and which has the potential to liberate a concentration of methane that is explosive or that could be capable of forming explosive mixtures with air). The subsurface facility will be monitored during construction and testing for methane gas presence and concentration.

The major ventilation system design features will include the following:

- The main fans will be installed on the surface, with reversing capability.
- The fans will be offset from the shaft and connected to it by a metallic air duct.
- Two identical fans will be installed in parallel, each capable of satisfying the airflow and pressure requirements; installation and wiring is such that in case of malfunction or sudden stop of one fan, the second will automatically start. A diesel standby generator will provide power to the fans if main power is lost.
- Each active face or testing area will be supplied with the flow rate required by applicable Mine Safety and Health Administration regulations (e.g., MSHA, 1987).
- Positive airflow will be provided at every working face.

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- Temporarily inactive dead-end drifts will be closed and posted against unauthorized entry.

- The fan installation will be equipped with and protected by a door in the duct that could function as an explosion door if needed.

8.4.2.2.2.2 Electrical systems

The electrical elements of the subsurface facility consist of the electrical power distribution systems, lighting systems, communication and alarm systems, and instrumentation systems.

The power distribution system consists of the incoming transmission line, Exploratory Shaft Facility main substation, surface-power distribution system, shaft distribution system, underground distribution system, and standby power system.

Currently at the Exploratory Shaft Facility, the incoming service is transformed at a main substation from 13.8 to 2.4 kV. From the 13.8- to 2.4-kV transformer, the power is distributed through the main switchgear via underground duct banks to 2.4-kV motor control centers and 480-V load centers. The 2.4-kV motor control center at the exploratory shaft switchgear house consists of motor controllers and switches necessary to supply control and distribution for the following Exploratory Shaft Facility loads:

- Exploratory Shaft 1 and Exploratory Shaft 2 hoists.

- Ventilation fans.

- Exploratory Shaft Facility support (e.g., pumps, heaters, chillers, shaft power, compressors, lighting, controls, trailers).

- 480 V subsurface substation at the hoist house.

The Exploratory Shaft Facility shaft power distribution system will consist of a three-phase, 480 V service that terminates at power stations located at intervals along the shaft. Each power station includes power receptacles with individual breakers to serve the shaft working platform, instrumentation, and the portable test drill and to test power.

The subsurface power distribution system will include a subsurface 2.4-kV motor control center, a 480-V substation, and a cable-tray system. The subsurface 2.4-kV motor control center will be supplied via a 5-kV cable routed down Exploratory Shaft 2. The 2.4-kV motor control center near the dewatering pumps will serve those pumps and distribute power to the 480-V substation near the office. The 480-V substation will supply power to the load centers and power receptacle stations. All cables will be distributed via the cable-tray system. The power receptacle stations will be located at convenient intervals throughout the drifts and will include two 480-V and one 120-V receptacle at each station. To provide adequate power, each receptacle will be supplied by a separate feeder. Each test area will include load centers supplying power to 240- and 120-V receptacles for use by test personnel.

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The standby power system will consist of 2,860-kW diesel engine generator with a rating sufficient to start and to run all standby loads. Standby loads include Exploratory Shaft 1 main and standby hoists, ventilation compressor No. 1, two dewatering pumps, and all necessary supporting apparatus. The standby power system will be available within 1 min of demand. The Exploratory Shaft Facility will be connected to all standby loads through isolation switches.

All communication systems will be backed by uninterruptible power that will supply power needs when either normal or standby power systems are unavailable. Instrumentation and computer systems that have uninterruptible power requirements will have individual uninterruptible power supply systems that meet power needs when either normal or standby power systems are unavailable.

Subsurface lighting will consist of permanent lighting for the drifts, selected test areas, operational areas (dewatering pumps, load center, shops), and office areas. Although the drift lighting would remain on during all activity phases, the remainder of the permanent lighting can be switched locally. High-level task lighting will be available and will consist of quartz fixtures mounted on portable stanchions.

The drift lighting will consist of high-pressure sodium, wall-mount luminaries attached to the cable-tray support channels at intervals sufficient to provide the desired illumination level. Although low-pressure sodium lamps develop a higher light output for equivalent power input, the color rendition is undesirable and, therefore, not recommended. Fluorescent fixtures, when present, will be suspended from the roof and are connected to power cables within the cable tray.

Battery-powered incandescent lighting and exit signs will be provided to light the egress route in the event of a power outage. These lights will be designed to operate between power loss and the time necessary to bring standby power on line and restrike the luminaries.

The communication and alarm systems will include telephones, voice-powered communications, two-way radios, and intercom/paging and signal/alarm networks. All communication and alarm systems have battery backup power and will be connected to normal and standby power sources. The communication and alarm systems will include both onsite and offsite capabilities.

The instrumentation systems include supervisory control, data acquisition, and monitoring. These systems monitor and control power, water supply, dewatering, air and ventilation, and in situ test monitoring. Necessary monitoring and control devices will be located on panels in a dedicated section of the Exploratory Shaft 1 main hoist house. There will be a dedicated data acquisition system to gather and store data from in situ tests. Communication will be from fixed and portable data acquisition "front-end" units via a fiber-optic link with the host computer on the surface. The system will meet all requirements necessary to obtain, transmit, and store Quality Level 1 data.

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8.4.2.2.2.3 Compressed air system

Compressed air will be available underground to support equipment for mining operations and testing procedures. The quantities necessary are listed in RKE/PB (1984; 1986). The quality of equipment air will be consistent with that required for the environmental air system.

During mine development, the contractor will be responsible for securing a source of equipment compressed air independent of the air distribution system at the Exploratory Shaft Facility. Equipment compressed air from underground construction will be distributed during mining operations by the contractor.

For testing procedures, compressed air piping will be extended from the Exploratory Shaft 1 shaft station to the test areas. An existing pipe in the Exploratory Shaft 1 shaft will be supplied by two equipment air compressors located in the Exploratory Shaft 1 hoist house. The system capacity will be based on the largest test demand--the hydraulic fracturing test.

8.4.2.2.2.4 Water supply system

Potable water will be supplied in portable, insulated containers or in portable drinking fountains in accordance with applicable regulations.

Service water will be available underground to support mining operations and testing procedures for the Exploratory Shaft Facility. During underground development, service water will be mainly used for drilling and for dust control during muck removal. When two or more drift faces are being developed simultaneously, drilling will be in progress at one face while much is being removed from the other face. The water demand during underground development, therefore, reflects a peak water use for all operations. During testing procedures, service water will be used on an intermittent basis during drilling and geophysical logging of boreholes. Service-water outlets with ball valves will be provided at a convenient spacing within the test drifts.

8.4.2.2.2.5 Sanitation system

Sanitary facilities will consist of portable units provided at convenient locations in the subsurface working areas of the Exploratory Shaft Facility in accordance with applicable regulations.

8.4.2.2.2.6 Dewatering system

During underground development below the water table, unexpected inflows of water are possible. An ongoing program of probe-hole drilling ahead of the drift face will be performed to detect geologic, hydrologic, or structural problems in or near the expected development path that could cause water inflows. This process has been described in Section 8.4.2.2.1. Expected water inflows used for the dewatering system design are included in WHC (1988) and will be finalized during definitive design.

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Two dewatering pumps will be a part of the Exploratory Shaft Facility dewatering facilities. These pumps will be either centrifugal or positive displacement pumps and are sized at about 750 L/min (200 gal/min) each. One pump is considered to be the normal duty pump, while the second is on standby. Pump capacity has been determined from expected inflow rates (see Section 6.1.2.4). Pump size will be reevaluated during definitive design based on recommendations in WHC (1988).

The pumps will discharge water from the main sump to the surface via the Exploratory Shaft 2 shaft through a 10-cm (4-in.) pipeline within one of the 18-cm (7-in.) annular pipes. Nominal capacity of the main sump is 100,000 L (26,300 gal).

The two vertical submersible pumps that will be installed in Exploratory Shaft 1 will be left in place during Exploratory Shaft Facility construction and will operate as backup pumps to the main dewatering pumps. They will be capable of pumping water to the surface during an emergency.

During outfitting and porthole test drilling of the Exploratory Shaft 2 shaft, before connecting Exploratory Shaft 1 and Exploratory Shaft 2, two contractor-furnished pumps will discharge water from the shaft sump through pipes to the surface.

It should be noted that currently available hydrologic data from Section 6.1.2.3 and WHC (1988) indicate that the flow from a typical inflow will decrease rapidly with time. The probe holes, sumps, and pumps will be designed to handle all projected water inflows. However, emergency evacuation requirements for a potential flooding event will be part of the definitive design basis for the Exploratory Shaft Facility.

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8.4.2.2.3 In situ testing

The actual locations of most of the tests needed to characterize the candidate repository environment or to define site characteristics within the Cohassett flow will be determined after the drifts are inspected for suitable geologic features representative of the candidate repository. Potential locations for this category of tests are shown in Figure 8.4-5. These tests, described in Sections 8.3.1 and 8.3.2, include the following:

- Exploratory borehole (Sections 8.3.1.2 and 8.3.1.3).
- Small and large flat jack (Section 8.3.2.2.3.1.3).
- Plate bearing (Section 8.3.2.2.3.3.4).
- Overcoring (Section 8.3.2.2.3.1.1).
- Hydraulic fracturing (Section 8.3.2.2.3.1.2).
- Thermal probe (Section 8.3.2.2.3.2).
- Rock support/deformation monitoring (Section 8.3.2.2.3).
- Borehole geophysics (Sections 8.3.1.2 and 8.3.2.2.3).
- Crosshole seismic (Sections 8.3.1.2 and 8.3.2.2.3.3.6).
- Ground-probing radar (Sections 8.3.1.2 and 8.3.2.2.3).

- Block shear (Section 8.3.2.2.3.3.5).
- Borehole jacking (Section 8.3.2.2.3.3.3).
- Proof of principle testing for retrieval (Section 8.2.2.2.4.2.6).

The remaining tests have the following specific locations (see Fig. 8.4-5):

- Chamber--chamber drift (Section 8.3.1.3).
- Full-scale heater--mine-by drift (Section 8.3.2.2.3.4.3).
- Room-scale heater--mine-by drift (Section 8.3.2.2.3.4.4).
- Mine-by--mine-by drift (Section 8.3.2.2.3.4.2).

Details pertaining to the conduct of the above tests are contained in study plans referenced from the sections in parentheses after the test name. Although no full-scale testing of postclosure drift seals is scheduled, the need for such testing will be evaluated as a part of the repository advanced conceptual design (see Section 8.3.3.4.1.3).

All data collected by the testing equipment (including porthole testing) will be transmitted to the surface and permanently stored as a part of the BWIP data base. All test equipment will be designed to interface with this data acquisition system through portable "front-end" units. Transmission to the surface will be via a fiber-optic link. Fault-tolerant (high-reliability) design requirements are imposed on the computer equipment used for project data base assimilation, storage, and retrieval.

Observation galleries will be constructed to allow monitoring of rock behavior during construction of the mine-by drift. From these galleries, instrumentation boreholes are drilled to measure tangential and radial stresses and deformations adjacent to the mine-by drifts. While the mine-by drift is being driven, the performance of the opening supports (rock bolts) will be monitored.

The planned sequence of the in situ testing is shown in Figure 8.4-14.

The Near-Surface Test Facility has been used, and will continue to be used, for development of tests and related equipment slated for use in the Exploratory Shaft Facility. Also, since the Near-Surface Test Facility consists of drifts in basalt, it will be used to train test personnel prior to conducting actual characterization testing in the Exploratory Shaft Facility.

8.4.2.3 Relationship of the Exploratory Shaft Facility location to the design of a repository

Repository planning has progressed to the point that the Exploratory Shaft Facility location within the planned repository is as shown in Figure 8.4-15. If the repository were to be located at the Hanford Site, the Exploratory Shaft Facility would be used as a staging area for initial repository drift development. Development would progress, as presently

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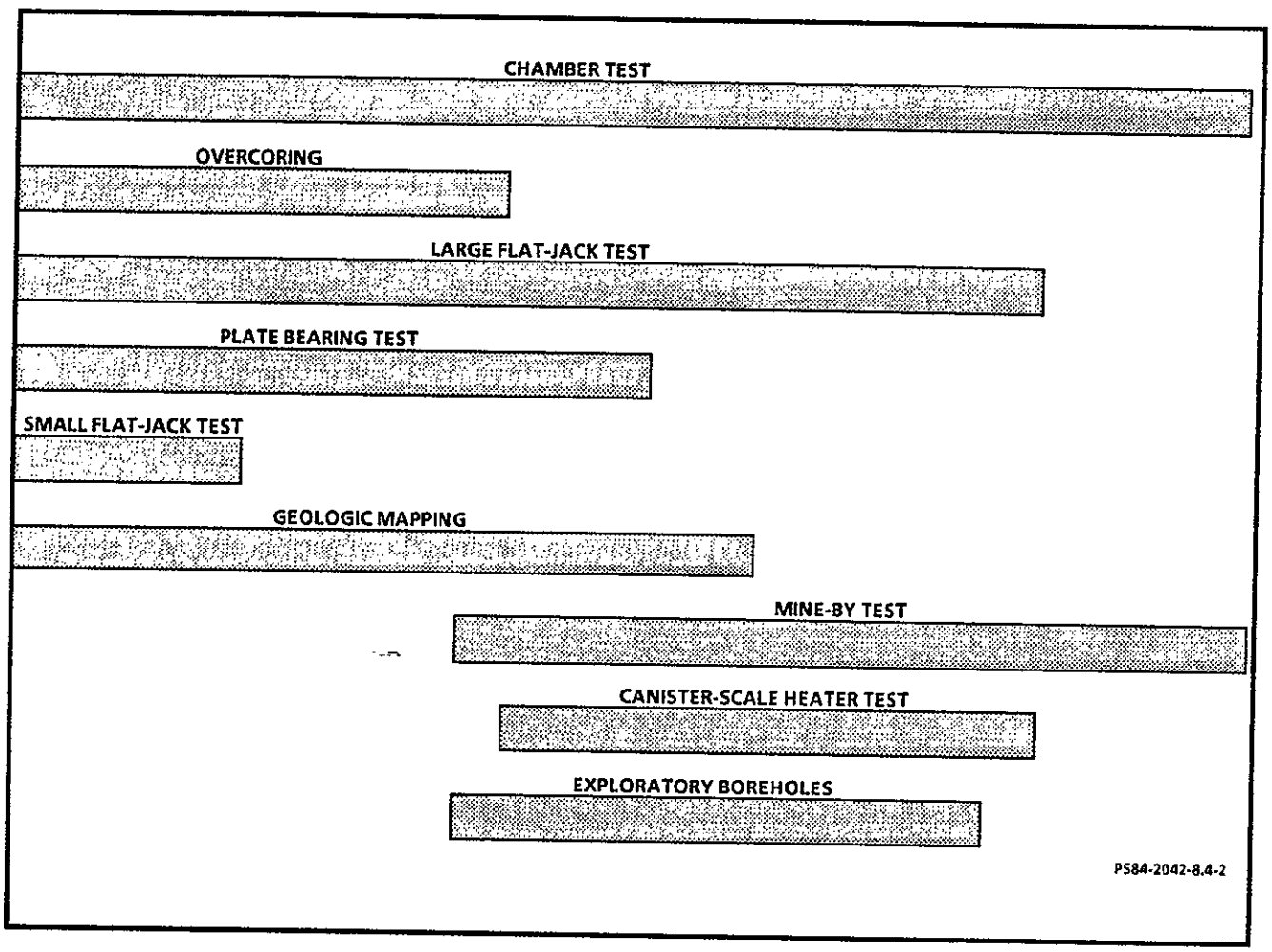

Figure 8.4-14. Underground in situ testing sequence.

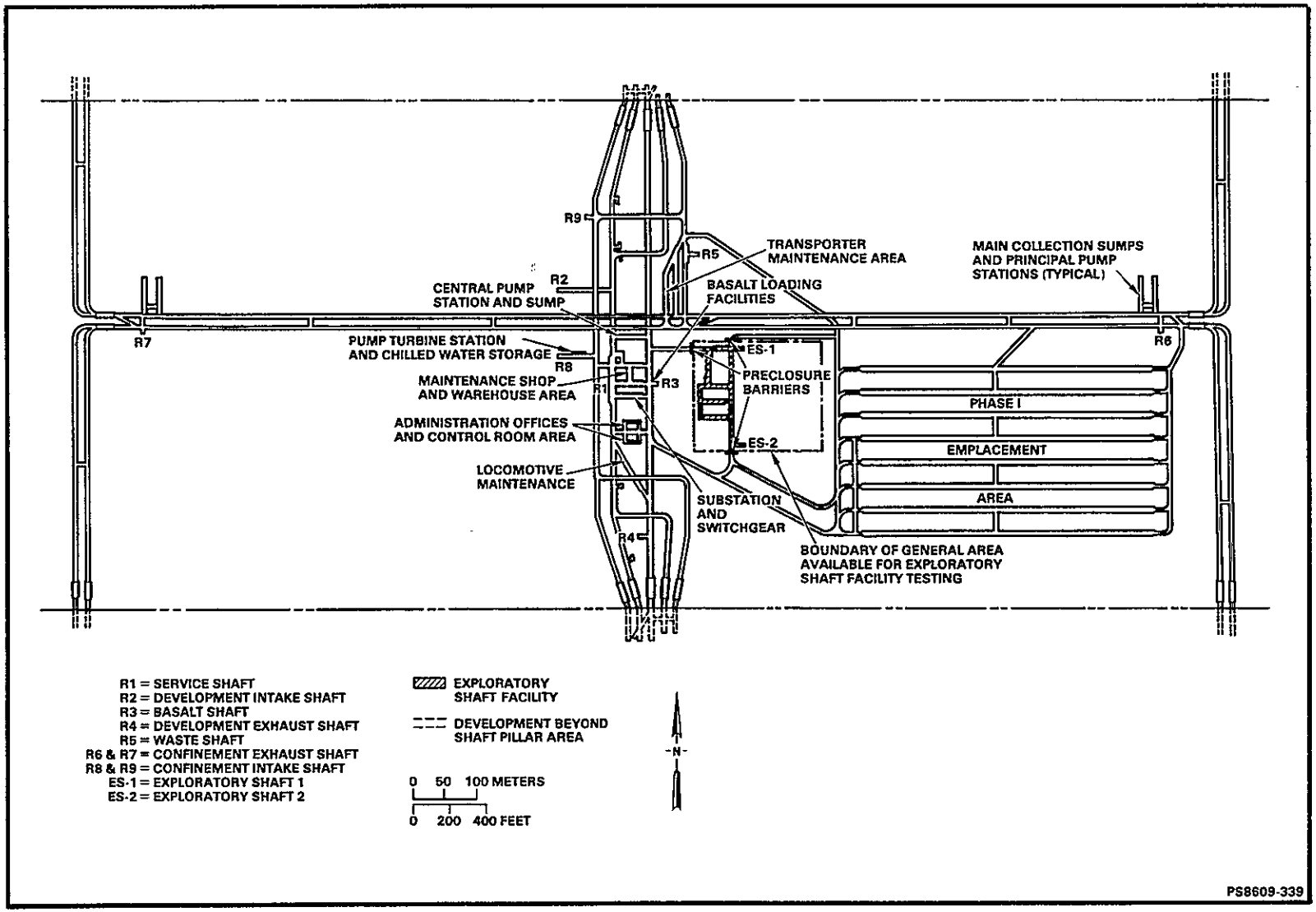

Figure 8.4-15. Exploratory Shaft Facility relationship to repository.

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envisioned, from the Exploratory Shaft Facility hydrology drift west and south to the vicinity of planned repository shafts (see Fig. 8.4-15). This gain of early access to the repository would have the potential to shorten the overall repository development schedule. The maximum size of this early development will probably be limited by the capacity of the Exploratory Shaft Facility ventilation system.

Final details on the extent of the Exploratory Shaft Facility use in repository operations will be evaluated in future studies. The following paragraph reflects the approach currently envisioned. Any impacts resulting from such studies will be reflected in this section.

Should the Exploratory Shaft Facility be used as a staging area for early repository development, present planning indicates that it will be sealed off from the repository by the installation of a preclosure ventilation and flooding barrier in the drifts at the Exploratory Shaft Facility boundary (see Fig. 8.4-15). This would be done prior to the time any radioactive waste is taken underground into the repository. Also the Exploratory Shaft Facility would not be used for any repository operations from the time of the installation of the barrier, but the Exploratory Shaft Facility would remain in use to complete any remaining testing. Postclosure isolation of the Exploratory Shaft Facility would use the same means as would be used for the repository.

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8.4.2.4 Potential impacts of exploratory shaft construction and testing on the waste isolation integrity of the site

This section addresses the potential impacts of construction of the Exploratory Shaft Facility and the Exploratory Shaft Facility testing program on the waste isolation integrity of the site. In 10 CFR 60 Subpart E, the NRC defines isolation as "inhibiting the transport of radioactive material so that amounts and concentrations of the materials entering the accessible environment will be kept within prescribed limits." During the first several hundred years following permanent closure, special emphasis is placed upon the ability "to contain the wastes by waste packages within an engineered barrier system." The waste package is composed of "the waste form and any containers, shielding, packing, and absorbent materials" surrounding the waste form. The engineered barrier system includes the waste packages and the underground facility. The underground facility "means the underground structure, including openings and backfill materials, but excluding shafts, boreholes and their seals."

8.4.2.4.1 Introduction and rationale

Paragraphs 60.112 and 60.113 of Subpart E, 10 CFR 60 (NRC, 1987) describe four postclosure performance objectives relating to (1) total system assessment of release of radionuclides to the accessible environment, (2) containment requirements for the waste package, (3) engineered barrier

system release rate, and (4) pre-waste-emplacement groundwater travel time. The DOE has incorporated these four objectives into the Issues Hierarchy for a Mined Geologic Disposal System (DOE, 1987b) under Key Issue 1. These four issues are listed in 8.2.2 and repeated below:

Issue 1.1 Will the mined geologic disposal system meet the system performance objective for limiting radionuclide releases to the accessible environment as required by 10 CFR 60.112 and 40 CFR 191.13?

Issue 1.4 Will the waste package meet the performance objective for containment as required by 10 CFR 60.113?

Issue 1.5 Will the waste package and repository engineered barrier systems meet the performance objectives for radionuclide release rates as required by 10 CFR 60.113?

Issue 1.6 Will the site meet the performance objective for pre-waste-emplacement groundwater travel time as required by 10 CFR 60.113?

The relationship of the NRC postclosure performance objectives to issues and issue resolution strategies is summarized in Table 8.4-1. In addition to the general discussion of issue resolution strategies given in Section 8.2.2, the specific potential impacts of Exploratory Shaft Facility construction and testing on each of these issues and on performance objectives are discussed in Sections 8.4.2.4.2 through 8.4.2.4.5.

Table 8.4-1. Relationship of postclosure performance objectives to issues and resolution strategies

Summary of postclosure performance objectives stated in 10 CFR 60 (NRC, 1987)	Corresponding issue number in Issues Hierarchy (DOE, 1987b)	Reference to issue resolution strategy in this SCP
Total system assessment of release of radionuclides to the accessible environment	1.1	8.2.2.1.1
Containment requirements for the waste package	1.4	8.2.2.1.4
Engineered barrier system release rate	1.5	8.2.2.1.5
Pre-waste-emplacement groundwater	1.6	8.2.2.1.6

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As stated in 8.4.2, the Exploratory Shaft Facility consists of two shafts, 3,000 ft of underground drifting covering an area of approximately 6 acres, and surface support facilities. The underground excavations are designed to remain structurally stable throughout the operating life of the repository, if required. The Exploratory Shaft Facility testing area will be at the repository level, 963 m (3,161 ft) below the surface. The testing area is physically separated from the Phase I waste emplacement area by approximately 150 m (500 ft). The testing area is located east of the Phase I emplacement area but within the repository shaft pillar area. The Exploratory Shaft Facility comprises a small fraction of the total repository area. Information on the shafts, drift dimensions, and penetration depths of the exploratory shafts is given in Section 8.4.2.

The testing program, which will be conducted in the Exploratory Shaft Facility, is discussed in Section 8.4.2.2.3. The major in situ tests include the mine-by test, the room-scale heater tests, the plate-bearing test, the flat jack tests, the hydraulic fracturing test, the chamber and cluster tests (hydrology), and various geophysical tests. Individual tests are not discussed in detail in this section. The assessment of the total test program impacts on the waste isolation integrity of the site is made in Sections 8.4.2.4.2 through 8.4.2.4.6.

The net effect of Exploratory Shaft Facility construction and testing can be categorized into three basic areas listed below:

- Create openings that will remain after construction and which could potentially furnish pathways for the movement of liquids and gases.
- Induce changes in the rock characteristics around these openings.
- Introduce solid liquid and gaseous materials to the site.

The extent of impacts caused by these modifications to the site are generally addressed in the following paragraphs. The potential impacts to each of the four postclosure performance objectives identified previously are specifically evaluated in Sections 8.4.2.4.2 through 8.4.2.4.5.

The openings and surrounding disturbed rock provide the potential for pathways for radionuclide travel in both the liquid and gaseous phases. These pathways include not only the shafts and drifts themselves but also the damaged rock zone caused by excavation of those openings. These impacts will be mitigated by backfilling the shafts and drifts to reduce the potential for flow of gases and liquids through these openings. In addition, it should be noted that the Exploratory Shaft Facility is designed to be physically separate from the nearby Phase I waste emplacement panels in the repository. Prior to repository closure, shaft seals will be installed to minimize water flow up or down the shaft disturbed zone from the aquifers. Seals will also be placed in the three drifts linking the Exploratory Shaft Facility to the rest of the repository, thereby minimizing any flow of groundwater into the repository from the Exploratory Shaft Facility.

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Construction-induced changes in the hydrologic characteristics of the rock mass surrounding an opening is limited to approximately 0.5 m (1.6 ft) around the repository shafts and 1.0 m (3.2 ft) around the excavation underground openings (Section 8.2.2.1.12.5.2). As shown in Figure 8.4-15, the Exploratory Shaft Facility comprises only a very small volume of pillar area. Therefore, the induced changes in rock characteristics are not expected to significantly change the overall hydrologic flow characteristics at the site, especially near waste emplacement panels, which are horizontally separated from the Exploratory Shaft Facility. Postclosure seals placed in the drifts separating the Exploratory Shaft Facility from the repository shaft pillar area will restrict the flow of any water toward or from the exploratory shafts. These seals are designated engineered barriers and provide the final separation of the Exploratory Shaft Facility and the emplaced Phase I waste, which is 150 m (500 ft) away.

The shaft postclosure system, including bulkheads, will restrict the flow of water. It is important to note that the decommissioning of the Exploratory Shaft Facility will be simultaneous with, and of the same design as, the repository.

Solid materials introduced to the site through the Exploratory Shaft Facility include the shaft liner, operational seals, and those materials used for testing purposes. The chemical interaction of the shaft liner and operational seals with the surrounding rock mass are expected to be limited to the disturbed zone surrounding the shaft. Materials used in testing will be removed and thus will also have no impact on the isolation integrity of the site.

Liquid materials introduced to the site are limited to water used during construction and to drilling fluids. As the shafts are drilled, it is expected that some drilling fluid will be introduced into the more permeable formations or basalt flow tops. However, the constituents of these fluids are designed to seal these more permeable areas. The total expected construction water volume used in the Exploratory Shaft Facility is relatively small, and no significant impacts on performance are expected. Since investigation of fluid movement at the site is an integral part of the planned site characterization activities, future data will be analyzed to determine the validity of this conclusion.

A significant amount of air will enter the Exploratory Shaft Facility through ventilation, and a lesser amount will enter through equipment using the compressed air system. The primary effects of the ventilation will be the removal of water and the reduction of ambient temperature. Air from the compressed air system will be exhausted from the Exploratory Shaft Facility through the ventilation system. Thus, the introduction of solid, liquid, and gaseous materials are transitory in nature and have no impact on the waste isolation integrity of the site.

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8.4.2.4.2 Impacts on groundwater travel time (Issue 1.6)

The issue resolution strategy for Issue 1.6 is based on the criterion in 10 CFR 60.113(a)(2) (NRC, 1987), which states the following:

> (2) *Geologic setting.* The geologic repository shall be located so that the pre-waste-emplacement groundwater travel time along the fastest path of likely radionuclide travel from the disturbed zone to the accessible environment shall be at least 1,000 years or such other travel time as may be approved or specified by the Commission.

Groundwater travel time is an indirect measure of the ability of the site subsystem to isolate radionuclides from the accessible environment. The system performance criterion, which is described in Section 8.2.2.1.1, limits the cumulative releases of radionuclides to the accessible environment for the first 10,000 yr after repository closure and measures the isolation capability of the repository system as a whole, including the site subsystem. Groundwater travel time measures the isolation provided by only one component of the repository system.

In the latest drift of their technical position paper on groundwater travel time criterion (NRC, 1986b), the NRC defines groundwater travel time to be the time of travel of an inert tracer particle that is advected along a pathline from a disturbed zone to the accessible environment. Any effect that molecular diffusion has on the displacement and time of travel of the particle is neglected in this definition. The estimated arrival time of the particle at the accessible environment boundary will have some associated uncertainty because the velocity field, which causes the advective motion of the particle, will not be perfectly known even after site characterization studies are completed. For this reason, the NRC favors the presentation of groundwater travel time estimates in the form of a cumulative probability distribution.

The pre-waste-emplacement modifier in the groundwater travel time criterion means that travel time is to be determined in the prevailing, undisturbed groundwater flow regime prior to any significant perturbation of the flow regime due to testing, repository construction, or repository operation (NRC, 1986b). The NRC (1986b) also states that groundwater travel time is to be calculated under the assumption that the present-day environmental conditions do not change, except in cases where significant transient behavior of the flow regime occurs. This means that the effects of anticipated and unanticipated events on the groundwater flow regime do not have to be accounted for when determining travel time. Disruptive events do have to be accounted for, however, in the evaluation of total system performance (see Section 8.2.2.1.1).

The starting points for the particles used to determine groundwater travel time are on the outer surface of the disturbed zone, which is a zone in the host rock immediately surrounding the repository where the physical or chemical properties have changed as a result of underground facility construction or as a result of heat generated by the emplaced radioactive wastes such that the resultant change of properties may have a significant effect on the performance of the geologic repository.

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A recent NRC position paper on the disturbed zone (NRC, 1986a) gave some guidelines on how the disturbed zone for a particular site might be determined. At the basalt site, the disturbed zone is expected to extend no more than a few diameters of the repository drifts into the host rock (see Section 8.3.2.2).

The proposed strategy for resolving Issue 1.6 and other background information may be found in Section 8.2.2.1.6. The geohydrologic testing program for the Hanford Site prior to the construction of the Exploratory Shaft Facility is described in Section 8.3.1.3. The proposed geohydrologic testing program has set a high priority on (1) establishing the hydraulic head baseline prior to construction of the Exploratory Shaft Facility and (2) finalizing the range of property values for the site after Exploratory Shaft Facility is constructed.

Establishing the hydraulic head baseline in the vicinity of the Exploratory Shaft Facility is considered important since it is assumed that construction and testing of this facility will obscure baseline conditions for the natural system. This is because the reestablishment of hydraulic baseline conditions are not expected to occur, after closure of the Exploratory Shaft Facility, in time to complete the license application design. Important information concerning the hydraulic properties of the site will be obtained from underground hydrologic testing in the Exploratory Shaft Facility. It is expected that some change in these properties will occur due to the construction of the Exploratory Shaft Facility but these changes will be restricted to the immediate vicinity of the shafts and drifts and will not extend beyond the edge of the Exploratory Shaft Facility disturbed zone.

Construction of and testing in the Exploratory Shaft Facility is not considered to affect resolution of Issue 1.6 for the following reasons:

- The hydraulic head measurements, which are necessary to compute gradients, flow paths, and groundwater travel time, are collected prior to construction of the Exploratory Shaft Facility.
- The change in hydrologic properties of the host rock due to construction and testing of the Exploratory Shaft Facility will be on a small enough scale to preclude a significant transient behavior to the flow regime so that groundwater travel time as defined by the NRC will not be affected.
- The disturbed zone of the Exploratory Shaft Facility is totally within the disturbed zone for the repository and, therefore, does not represent a groundwater travel time starting point.

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8.4.2.4.3 Potential impacts on container lifetime (Issue 1.4)

The issue resolution strategy for Issue 1.4 is based on the requirements in 10 CFR 60.113(a)(1)(ii) (NRC, 1987), which specify that the engineered barrier system shall be designed, assuming anticipated processes and events, so that:

> (A) Containment of HLW within the waste packages will be substantially complete for a period to be determined by the Commission taking into account the factors specified in 60.113(b), provided that such period shall be not less than 300 years nor more than 1,000 years after permanent closure of the geologic repository;...

To guide the testing and design programs for obtaining the information needed to assess the performance of the set of waste packages, quantitative design objectives have been set by the DOE. These design objectives are consistent with the general interpretation given above in order to focus the site characterization program on the requirements for substantially complete containment.

The design objectives (current program) are as follows:

- By virtue of the intrinsic properties and design of the waste package components subjected to the range of conditions anticipated in the underground facility, 80% or more of the waste packages will retain all their radioactivity for a containment period of 1,000 yr after permanent closure of the repository.

- At any time during the containment period, at least 99% of the radioactivity resulting from the original waste emplaced in the underground facility will be retained within the set of waste packages.

- Any releases from the waste packages that occur during the containment period should be gradual, such that releases from the engineered barrier system in any year during this period should not exceed one part in 100,000 of the total inventory of radionuclide activity present in the geologic repository system in that year.

Additional details on the interpretation of the regulatory requirements and other background information are provided in Section 8.2.2.1.4.1.

The licensing strategy for the waste package is composed of a program strategy and two technical strategies (i.e., reference and alternate). The program strategy defines the combinations of subsystem elements assigned to satisfy the requirements of substantially complete containment and is described in detail in Section 8.2.2.1.4.2.

The program strategy depicts the upper level of the licensing strategy for development of the BWIP waste package subsystem. The reference technical strategy for meeting the substantially complete containment requirement is to

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rely on the container and the packing as complementary barriers and to show that together they are capable of satisfying the DOE objectives and goals for the substantially complete containment.

An important underlying criterion for the waste package development is that, to the extent practicable, the engineered components of the waste package will be selected from candidate materials that are near thermodynamic equilibrium with respect to the natural materials and long-term environmental conditions that will envelop the waste package after emplacement and after closure. Adherence to this criterion in implementing the technical assignments of the strategy should help to minimize the potential for degradation of the waste package components. Minimizing the potential for degradation will enhance confidence in the predictions of waste package performance and in the validity of the natural analog data that may be used to support claims for long-term materials performance capabilities.

The construction and operation of the Exploratory Shaft Facility is expected to have no effect on the ability of the set of emplaced waste packages to meet the container lifetime requirement. A discussion supporting this conclusion is provided below.

Irrespective of the presence of an Exploratory Shaft Facility, the construction of the underground facility will necessarily alter the preconstruction environment at repository depth. Excavation will create a temporary pressure sink to 0.10 MPa (1 bar) that will tend to draw groundwater toward the underground facility, dewatering the host rock in the vicinity of the excavation. Some fracturing of the host rock nearest the underground facility will occur, potentially altering groundwater pathways in the near field. Emplacement of the high-level waste containers will result in increased temperatures and will expose the near field to low levels of ionizing radiation.

During excavation and operation and prior to repository closure, the repository underground facility will be exposed to a humid (100% relative humidity) air environment. Repository closure is expected to prevent further introduction of air into the underground facility. Following closure, it is expected that the underground facility, and in particular, the waste packages, will remain in an unsaturated environment for a significant length of time. The duration of this phase of repository history depends on the resaturation process, which is not yet well understood. A gradual progression in environmental conditions is expected from a gas phase air/steam environment at a pressure of 0.10 MPa (1 bar) to an intermediate two-phase system of nitrogen/water/methane and groundwater, to a saturated groundwater system at hydrostatic pressure 9.4 MPa (94 bars). Ultimately, the repository will become fully saturated with altered basalt groundwater, and the general conditions in the repository underground facility are expected to gradually change toward those present in the basalt flow prior to repository construction. This sequence of events is not expected to be affected by the Exploratory Shaft Facility. A more complete discussion of the repository environment is provided in Sections 7.1 and 7.4.1.

The Exploratory Shaft Facility might be postulated to affect the waste package container lifetime through mechanical or chemical processes that would alter the waste package environment. No such processes have been identified that could significantly affect this environment.

The Exploratory Shaft Facility might be postulated to affect the waste package container lifetime through mechanical or chemical processes that would alter the waste package environment. No such processes have been identified that could significantly affect this environment.

The Exploratory Shaft Facility is at least 150 m (500 ft) from the nearest waste package, and any mechanical effects of the facility would be mitigated by the host rock between the Exploratory Shaft Facility and the nearest waste packages. There are no unique features of the Exploratory Shaft Facility that are significantly different than features of the rest of the underground facility that would be expected to have any effect on the mechanical environment of the waste packages.

There are no materials in the Exploratory Shaft Facility that would cause a significant change to the chemical environment of the waste packages. The construction materials for the Exploratory Shaft Facility are expected to be of the same type as those to be used for the repository underground facility. A study of repository construction materials is planned and described in Section 8.3.4.2.3. The portland cement in concrete and grout has been identified as one material with the potential to affect waste package performance. This material is not unique to the Exploratory Shaft Facility. Other materials that may be used while conducting tests are expected to be removed before repository closure. Any trace amounts of materials remaining after cleanup are expected to be negligibly small and are far (150 m (500 ft)) from the nearest waste packages. These materials should not have any significant effect on container lifetime.

In summary, no scenarios have been identified that would be expected to result in the Exploratory Shaft Facility having a unique or significant effect on waste package container lifetime.

8.4.2.4.4 Potential impacts on engineered barrier system release (Issue 1.5)

The issue resolution strategy for Issue 1.5 is based on the requirements of 10 CFR 60.113(a)(1)(ii) (NRC, 1987), which specify that the engineered barrier system shall be designed, assuming anticipated processes and events, so that:

> (B) The release rate of any radionuclide from the engineered barrier system following the containment period shall not exceed one part in 100,000 per year of the inventory of that radionuclide calculated to be present at 1,000 years following permanent closure, or such other fraction of the inventory as may be approved or specified by the

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Commission; provided, that this requirement does not apply to any radionuclide which is released at a rate less than 0.1% of the calculated total release rate limit. The calculated total release rate limit shall be one part in 100,000 per year of the inventory of radioactive waste, originally emplaced in the underground facility, that remains after 1,000 years of radioactive decay.

The components in the engineered barrier system that are being relied on to limit radionuclide release include the container (including container filler), the packing, and the waste form. Additional details on the interpretation of the regulatory requirements and other background information are provided in Section 8.2.2.1.5.1.

The licensing strategy for the engineered barrier system is composed of a program strategy and two technical strategies (i.e., reference and alternate). The program strategy defines the combinations of subsystem elements assigned to satisfy the requirements of substantially complete containment and is described in detail in Section 8.2.2.1.5.2.

This program strategy also depicts the upper level of the licensing strategy for development of the BWIP waste package subsystem. The reference technical strategy for meeting the substantially complete containment requirements is to rely on the container and the packing as complementary barriers and to show that together they are capable of satisfying the NRC radionuclide release criteria. In the reference strategy the container will contribute to satisfying the radionuclide release rate requirement via distributed container failure. The packing contributes to meeting this requirement by providing an environment that limits radionuclide solubility and the low permeability of packing assists by limiting mass transport. The alternate strategy also relies on the spent fuel waste form to limit radionuclide release by stoichiometric dissolution.

The construction and operation of the Exploratory Shaft Facility is expected to have no effect on the ability of the emplaced waste packages to meet the controlled release rate requirement. A discussion supporting this conclusion is provided below.

Irrespective of the presence of an Exploratory Shaft Facility, the construction of the repository underground facility will necessarily alter the preconstruction environment at repository depth. Excavation will create a temporary pressure sink to 0.10 MPa (1 bar) that will tend to draw groundwater toward the underground facility, dewatering the host rock in the vicinity of the excavation. Some fracturing of the host rock nearest the underground facility will occur, potentially altering groundwater pathways in the near field. Emplacement of the high-level waste containers will result in increased temperatures and will expose the near field to low levels of ionizing radiation.

During excavation and operation and prior to repository closure, the repository underground facility will be exposed to a humid (100% relative humidity) air environment. Repository closure is expected to prevent further

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introduction of air into the underground facility. Following closure, it is expected that the underground facility, and in particular the waste packages, will remain in an unsaturated environment for a significant length of time. The duration of this phase of repository history depends on the resaturation process, which is not yet well understood. A gradual progression in environmental conditions is expected from a gas phase air/steam environment at a pressure of 0.10 MPa (1 bar) to an intermediate two-phase system of nitrogen/water/methane and groundwater, to a saturated groundwater system at hydrostatic pressure 9.4 MPa (94 bars). Ultimately, the repository will become fully saturated with altered basalt groundwater, and the general conditions in the repository underground facility are expected to gradually change toward those present in the basalt flow prior to repository construction. This sequence of events is not expected to be affected by the Exploratory Shaft Facility. A more complete discussion of the repository environment is provided in Sections 7.1 and 7.4.1.

The Exploratory Shaft Facility might be postulated to affect radionuclide behavior through mechanical or chemical processes that would alter the waste package environment. No such processes have yet been identified that could significantly affect this environment.

The Exploratory Shaft Facility is at least 150 m (500 ft) from the nearest waste package, and any mechanical effects of the facility would be mitigated by the host rock between the Exploratory Shaft Facility and the nearest waste packages. There are no unique features of the Exploratory Shaft Facility that are significantly different than the repository underground facility that would have any effect on the mechanical environment of the waste packages.

There are no materials in the Exploratory Shaft Facility that would cause a significant change to the chemical environment of the waste packages. The construction materials for the Exploratory Shaft Facility are expected to be the same as those for the balance of the repository underground facility. A study of repository construction materials is planned and described in Section 8.3.4.2.3. The portland cement in concrete and grout has been identified as one material with the potential to affect waste package performance. This material is not unique to the Exploratory Shaft Facility. Other materials that may be used while conducting tests in the Exploratory Shaft Facility are expected to be removed after cleanup are expected to be negligibly small and are far (150 m (500 ft)) from the nearest waste packages. The long period of time prior to the controlled release period (1,000 yr) should be more than sufficient to remove any chemical perturbations in the waste package environment that might influence radionuclide behavior.

In summary, no mechanisms have been identified that would result in the Exploratory Shaft Facility having a unique or significant effect on the release rate of radionuclides from the engineered barrier system.

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8.4.2.4.5 Impact on release to the accessible environment (Issue 1.1)

The issue resolution strategy for Issue 1.1, release to accessible environment, is presented in Section 8.2.2.1.1. The essence of the strategy is to prove that the hydrogeologic and hydrochemical characteristics of natural and man-made pathways from the repository will restrict the release and transport of radionuclides such that cumulative release to the accessible environment in 10,000 yr will be less than the limits allowed by 40 CFR 191 (EPA, 1986).

As noted in Section 8.2.2.1.1.2, the site geohydrologic characteristics are expected to provide slow convective groundwater and radionuclide movement through the site subsystem, primarily through flow tops. Most of the radionuclide transport that does occur will be characterized by vertically upward movement through the repository horizon (i.e., the Cohassett flow interior) followed by horizontal migration to the accessible environment confined within the Cohassett flow top. Adsorptive properties of the flow interior and flow top minerals are expected to restrict the transport of all radionuclides except ^{129}I and ^{14}C for durations substantially in excess of 10,000 yr. The geochemical and physical characteristics of the host rock are expected to control the release rate of ^{14}C such that, even with a short radionuclide travel time, there is very low probability that the performance objective would not be met. The inventory of ^{129}I in spent fuel is insufficient to exceed the allowable cumulative release limit by itself; the release rate for ^{129}I is therefore not a significant factor in determining system capability.

Preliminary analyses of the repository seals subsystem, summarized in Section 8.2.2.1.1.1.2, indicate that groundwater transport, and therefore radionuclide transport, through the shaft seals represents a very small fraction of the groundwater flux through the repository. It would therefore be expected that the exploratory shafts, physically similar to the operational shafts of the repository but more remote from the waste emplacement rooms, would represent a small increment to a minor radionuclide pathway. The strategy for resolution of Issue 1.1 includes characterization of the shaft seals and surrounding rock in sufficient detail to model radionuclide transport through the shafts either to the surface or to flow tops above the Cohassett flow interior. If the preliminary analyses cited previously are substantiated, it can be concluded that the sealed shafts, including the exploratory shafts, do not represent a preferential pathway for radionuclide migration and therefore do not compromise the isolation capability of the overall system.

An important point in th preceding paragraph is that the Exploratory Shaft Facility, if constructed and tested within the bounds of reasonable constraints that preclude excessive damage or contamination during the construction and test periods, is unlikely to compromise the isolation capability of the geologic repository system. For example, in the construction phase, any testing of alternative excavation methods would not include methods likely to damage substantial amounts of rock adjacent to the shaft excavation.

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Similarly, during testing, destructive testing of waste packages and use of radioactive tracers will be restricted such that the contamination of the Exploratory Shaft Facility will be totally avoided. In addition to these constraints on construction and testing, the Exploratory Shaft Facility will be constructed in a location sufficiently close to the planned operational shafts to ensure representativeness of the excavated strata but sufficiently remote to minimize the potential for creating a preferential pathway for radionuclide migration to the accessible environment. If the Exploratory Shaft Facility is connected by an access drift to the operational shafts during any portion of the repository construction or operating phases, that access will be sealed prior to repository closure.

It is evident from the discussion presented in this section that construction and testing of the Exploratory Shaft Facility is unlikely to affect the ability of the geologic repository system to comply with the performance objective for Issue 1.1, release to the accessible environment.

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8.4.2.4.6 Conclusion

The potential impacts of Exploratory Shaft Facility construction and testing on performance are not expected to be significant because (1) the exploratory shafts will be sealed from the aquifers by shaft seals and bulkheads of the same design as those for the repository shafts, (2) the Exploratory Shaft Facility will be sealed, at closure, from the rest of the repository by drift seals that are part of the engineered barrier system, (3) the effect of construction on the rock mass surrounding the openings is limited in extent, (4) liquids and solids introduced by construction and testing are expected to be minimal and move only a short distance (a few meters) into the rock mass, and (5) the Exploratory Shaft Facility is laterally separated from waste-emplacement panels by at least 150 m (500 ft). These evaluations are based on current knowledge of the site.

The net effects of construction and testing are confined to the immediate area of the Exploratory Shaft Facility. Upon construction of the repository, the remaining components of the Exploratory Shaft Facility by definition become part of the repository. As such, operations and decommissioning will be done to the same design and at the same time as the repository shafts and pillars.

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*A decision on July 17, 1987, by the U.S. Court of Appeals for the First Circuit has required the EPA to reconsider its postclosure standards (Subpart B) in 40 CFR 191. Consequently, the standards in 40 CFR 191 may be subject to revision in the future.

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SITE CHARACTERIZATION PLAN

Chapter 8 - SITE CHARACTERIZATION PROGRAM

Section 8.5

Milestones, Decision Points, and Schedule

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8.5 MILESTONES, DECISION POINTS, AND SCHEDULE

The Geologic Repositories Program (and, therefore, the Basalt Waste Isolation Project (BWIP)) is directed to follow the institutional process established by Congress in the Nuclear Waste Policy Act (NWPA) (NWPA, 1983). This process includes state, Indian tribe, and public involvement in site characterization activities, leading to U.S. Department of Energy (DOE) site recommendation, presidential site recommendation, congressional approval of the site, and U.S. Nuclear Regulatory Commission (NRC) licensing.

To determine the required activities, a logical sequence of events must be established. A first step in developing a project logic is to identify the major program phases. Each phase represents a stage in the life of a program, covering the period from authorization to completion. Major phases establish manageable increments of work for program control and mission accomplishment. The DOE established the major program phases to culminate in the isolation of waste in a geologic repository. The major program phases are identified in Figure 8.5-1.

- Site Investigation Phase--This phase consists of gathering and assessing the information required to show that the basalt medium meets applicable criteria for characterization. At the Hanford Site, investigations were started several years prior to passage of the NWPA. Based on siting guidelines (contained in 10 CFR 960, DOE, 1987) and environmental assessments of several sites, the DOE recommended three candidate sites for characterization. The site investigation phase concluded when the President approved the recommendation.

- Site Characterization Phase--With the selection of the reference repository location on the Hanford Site as one of the three approved candidate sites, a site characterization plan (SCP) is being issued and the necessary permits to proceed will be obtained. In accordance with the SCP, extensive data will be collected pertaining to the site, including information from an in situ test facility in the reference repository horizon (the Exploratory Shaft Facility). The development of technology and design of facilities for permanent disposal of waste will also be accomplished as necessary for support of a license application.

  Based on the environmental impact statement from the candidate sites being characterized and ongoing safety analyses of the selected design concepts, the DOE will submit a site selection report to the President. After reviews by the President, states, Indian tribes, and Congress, this phase will conclude with the designation of a site for the first repository.

- Construction Phase--The DOE will submit a license application to the NRC for the designated site. Final procurement and construction design for the repository will be completed during the license application review period. Confirmatory testing will continue throughout this phase.

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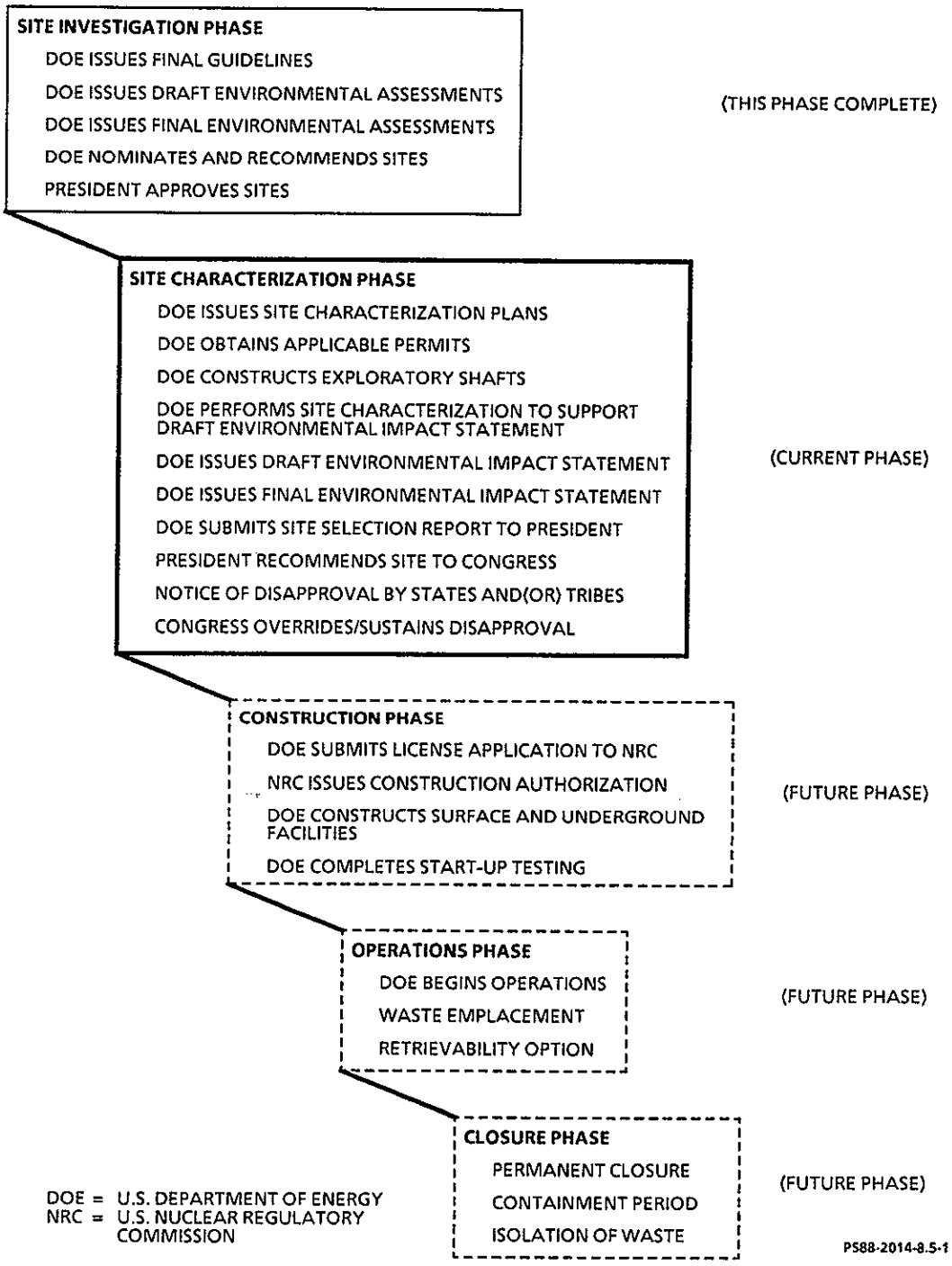

Figure 8.5-1. Major program phases.

9 2 1 2 5 5 1 0 3 2

The present concept is for the repository to be constructed in two phases. Construction of both phases starts when the construction authorization is issued by the NRC. When start-up testing of the smaller Phase I is complete, the NRC will issue an operations license.

- Operations Phase--This phase begins with storage of the first waste in the Phase I repository. In addition to waste emplacement and monitoring operations, activities include completion of Phase 2 repository facilities and continued mining of the underground facility. Confirmatory testing will continue throughout this phase.

  At the completion of waste emplacement and the end of the retrievability option, the DOE will submit an application to amend the license to permit closure. This phase concludes when the NRC amends the license to authorize permanent closure.

- Closure Phase--Closure will include final backfilling, sealing shafts and boreholes, decommissioning surface facilities, and implementing institutional barriers to human intrusion.

  After the repository is permanently closed, this phase will consist of monitoring and containment of waste for the first several hundred years. After the initial containment period, the waste will be isolated from the accessible environment by the natural and engineered barrier subsystem. After 10,000 yr of isolation, this phase is concluded and the system mission completed.

The information presented in this chapter is intended to accumulate the BWIP schedule and logic information contained in the various sections of Chapter 8.3 into an overall schedule of site characterization phase activities. Sections 8.5.1 through 8.5.4 present summary schedules for the individual programs and associated investigations (or activities) involved in the overall programs for site, performance assessment, repository, and waste package, respectively. Section 8.5.5 presents the major project decisions to be made during the site characterization phase, along with the current assessment of their likely outcome. Section 8.5.6 presents an overall summary schedule for the project, along with many of the major programmatic milestones that mark key events along the course of the project.

It should be noted that, because of ongoing planning efforts and associated schedule uncertainties, no specific dates are included on the schedules. The schedule information provided includes the sequencing, interrelationships, and relative durations of activities in the overall program. Specific durations and start/finish dates for the individual programs are being developed as part of the ongoing planning efforts; these will be provided in the SCP at the time of issuance and will be revised as appropriate in subsequent semi-annual progress reports.

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8.5.1 SITE PROGRAM ACTIVITIES

The investigation-level schedules contained in the various subsections of Section 8.3.1 have been summarized and are presented in Figure 8.5-2. The schedule includes the specific programs (geology, hydrology, geochemistry, climatology, and resource potential) that make up the site portion of the total program. Each specific program is supported by the individual investigation-level schedules taken from Section 8.3.1.

In addition to the relative schedule relationships between investigations, certain key major events have been identified as appropriate to define controlling interrelationships between programs.

8.5.2 PERFORMANCE ASSESSMENT PROGRAM ACTIVITIES

The activity-level schedules contained in the various subsections of Section 8.3.5 have been summarized and are presented in Figure 8.5-3. The schedule includes the specific programs for preclosure and postclosure assessments that make up the total performance assessment portion of the program.

Key major events have been identified as appropriate to define controlling interrelationships between programs.

8.5.3 REPOSITORY PROGRAM ACTIVITIES

The investigation-level schedules contained in the various subsections of Sections 8.3.2 and 8.3.3 have been summarized and are presented in Figures 8.5-4 and 8.5-5. The schedule in Figure 8.5-4 includes the specific programs for host rock environment, design optimization, repository modeling, and waste retrieval as discussed in Section 8.3.2. The schedule in Figure 8.5-5 includes the specific programs described in Section 8.3.3 for seals subsystem components and interaction testing, seals system design optimization, and seals system modeling. All of these specific programs are included in the repository portion of the total program. Each specific program is supported by the individual investigation-level schedules taken from either Section 8.3.2 or 8.3.3.

In addition to the relative schedule relationships between investigations, certain key major events have been identified as appropriate to define controlling interrelationships between programs.

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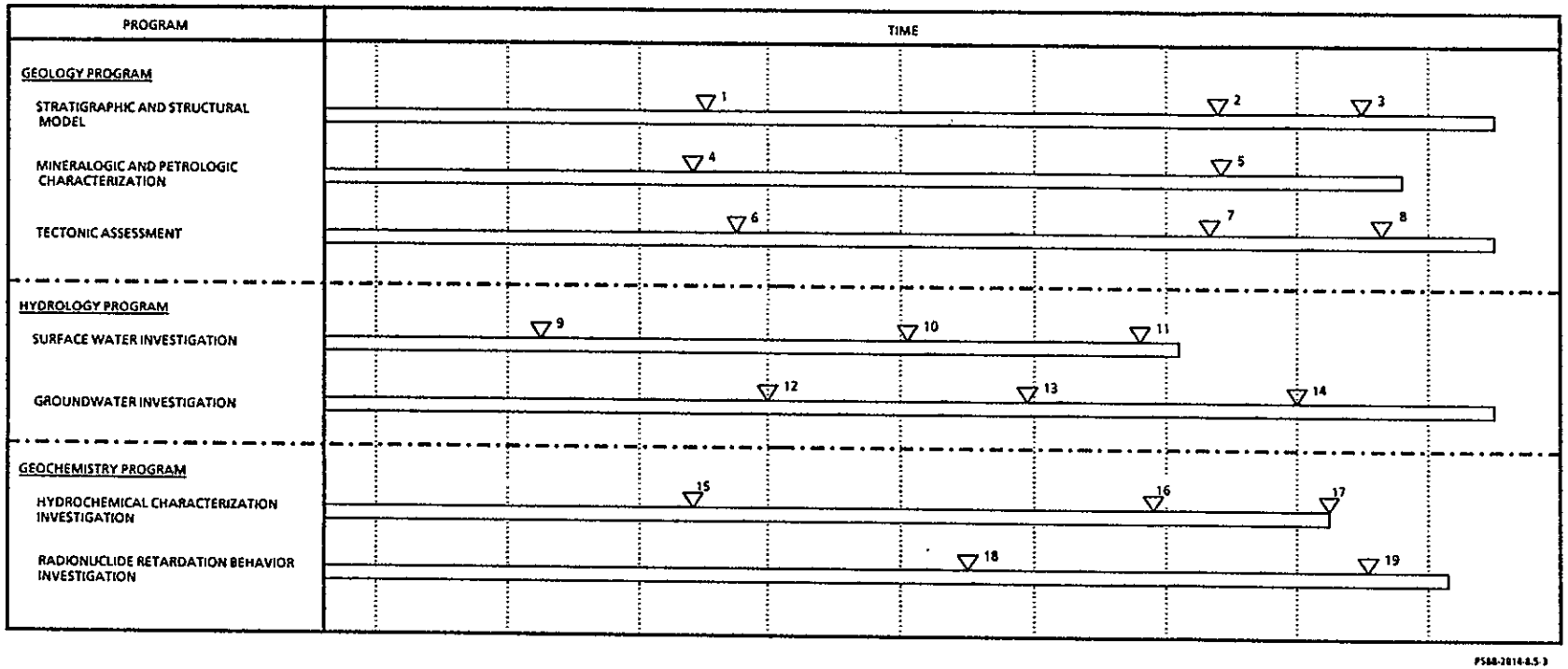

Figure 8.5-2. Site program schedule. (sheet 1 of 2)

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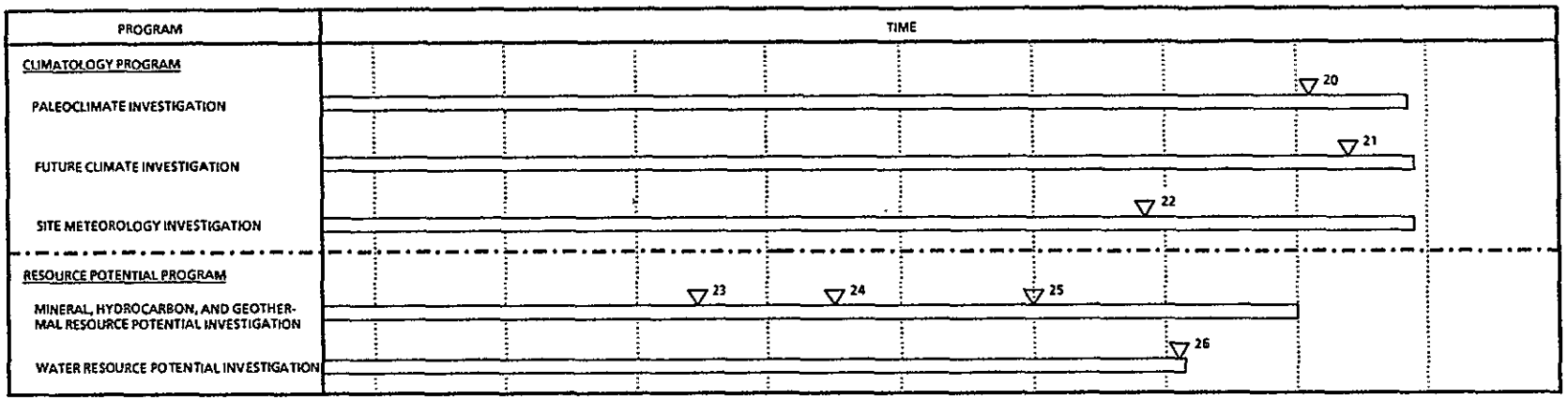

1 PRELIMINARY STRATIGRAPHIC AND STRUCTURAL INPUT TO ACD.
2 FINAL STRATIGRAPHIC AND STRUCTURAL INPUT TO LAD
3 FINAL STRATIGRAPHIC AND STRUCTURAL INPUT TO THE DEIS.
4 SUMMARIZE MINERALOGY AND PETROLOGY CHARACTERISTICS OF CASZ FOR ACD.
5 COMPLETE FINAL INPUT ON MINERALOGY AND PETROLOGY FOR LAD AND ISSUE 1.8.
6 COMPLETE INPUT ON TECTONIC EVENTS AND PROCESSES TO ACD.
7 COMPLETE INPUT ON TECTONIC EVENTS AND PROCESSES TO LAD.
8 COMPLETE INPUT ON TECTONIC EVENTS AND PROCESSES TO THE DEIS.
9 PRELIMINARY SITE FLOODING CALCULATIONS FOR ENGINEERING DESIGN.
10 FINAL SITE FLOODING CALCULATIONS FOR FACILITY DESIGN AND LICENSE APPLICATION SUPPORT.
11 FINAL EVALUATION OF WATERSHED AND HYDROLOGIC DATA.
12 PERISHABLE SITE HYDROGEOLOGIC DATA COLLECTION COMPLETED.
13 REGIONAL GROUNDWATER CONCEPTUAL MODEL FINALIZED.
14 SITE GROUNDWATER TESTING COMPLETED
15 PROVIDE HYDROCHEMISTRY DATA STATUS REPORT
16 COMPLETE CONCEPTUAL MODEL OF RADIONUCLIDE REDOX BEHAVIOR AND REDOX CAPACITY
17 COMPLETE DETERMINATION OF FLOW VECTORS.
18 COMPLETE PRELIMINARY SORPTION PARAMETER DATA BASE FOR PERFORMANCE ASSESSMENT MODELING.
19 COMPLETE FIELD AND LABORATORY SORPTION PARAMETER DATA BASE FOR PERFORMANCE ASSESSMENT MODELING OF RADIONUCLIDE TRANSPORT.
20 FINAL CLIMATE RECONSTRUCTION AT 3,000-YR INTERVALS PROVIDED TO THE FUTURE CLIMATE CHANGE INVESTIGATION.
21 FUTURE CLIMATE FORECASTS COMPLETED.
22 CHARACTERISTICS AND SPATIAL VARIATION OF PRECIPITATION PROVIDED TO THE SURFACE WATER SYSTEM STUDY
23 MINERAL RESOURCE POTENTIAL ASSESSMENT DATA BASE COMPLETE FOR PERFORMANCE ASSESSMENT.
24 GEOTHERMAL RESOURCE POTENTIAL ASSESSMENT DATA BASE COMPLETE FOR PERFORMANCE ASSESSMENT.
25 HYDROCARBON RESOURCE POTENTIAL ASSESSMENT DATA BASE COMPLETE FOR PERFORMANCE ASSESSMENT
26 ANALYSIS OF SINGLE- AND MULTIPLE-PROJECT SCENARIOS ON CASZ BOUNDARY CONDITIONS COMPLETED

ACD = ADVANCED CONCEPTUAL DESIGN
CASZ = CONTROLLED AREA STUDY ZONE
DEIS = DRAFT ENVIRONMENTAL IMPACT STATEMENT
LAD = LICENSE APPLICATION DESIGN

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Figure 8.5-2. Site program schedule. (sheet 2 of 2)

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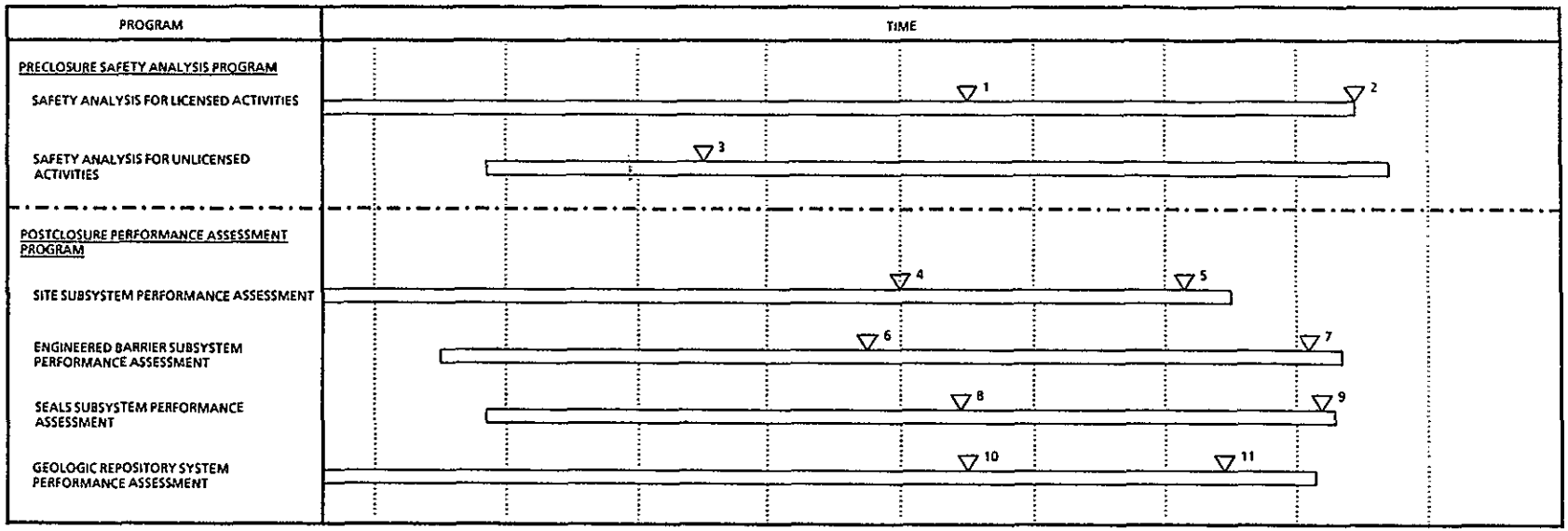

1 ACD SAFETY ASSESSMENT COMPLETE
2 COMPLETION OF RESOLUTION OF ISSUES 2.1, 2.2, 2 3, AND 2.5 AND LAD SAFETY ANALYSIS.
3 ISSUE EXPLORATORY SHAFT FACILITY SAFETY ANALYSIS REPORT.
4 COMPLETE GROUNDWATER TRAVEL TIME ANALYSIS IN SUPPORT OF ACD PERFORMANCE ASSESSMENT.
5 COMPLETE GROUNDWATER TRAVEL TIME ANALYSIS IN SUPPORT OF LAD PERFORMANCE ASSESSMENT
6 COMPLETE ENGINEERED BARRIERS PERFORMANCE ASSESSMENT FOR ACD.
7 COMPLETE ENGINEERED BARRIERS PERFORMANCE ASSESSMENT FOR LAD
8 COMPLETE SEALS PERFORMANCE ASSESSMENT FOR ACD
9 COMPLETE SEALS PERFORMANCE ASSESSMENT FOR LAD.
10 CONDUCT POSTCLOSURE PERFORMANCE ASSESSMENT OF TOTAL SYSTEM FOR ACD
11 CONDUCT POSTCLOSURE PERFORMANCE ASSESSMENT OF TOTAL SYSTEM FOR LAD

ACD = ADVANCED CONCEPTUAL DESIGN
LAD = LICENSE APPLICATION DESIGN

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Figure 8.5-3. Performance assessment program schedule.

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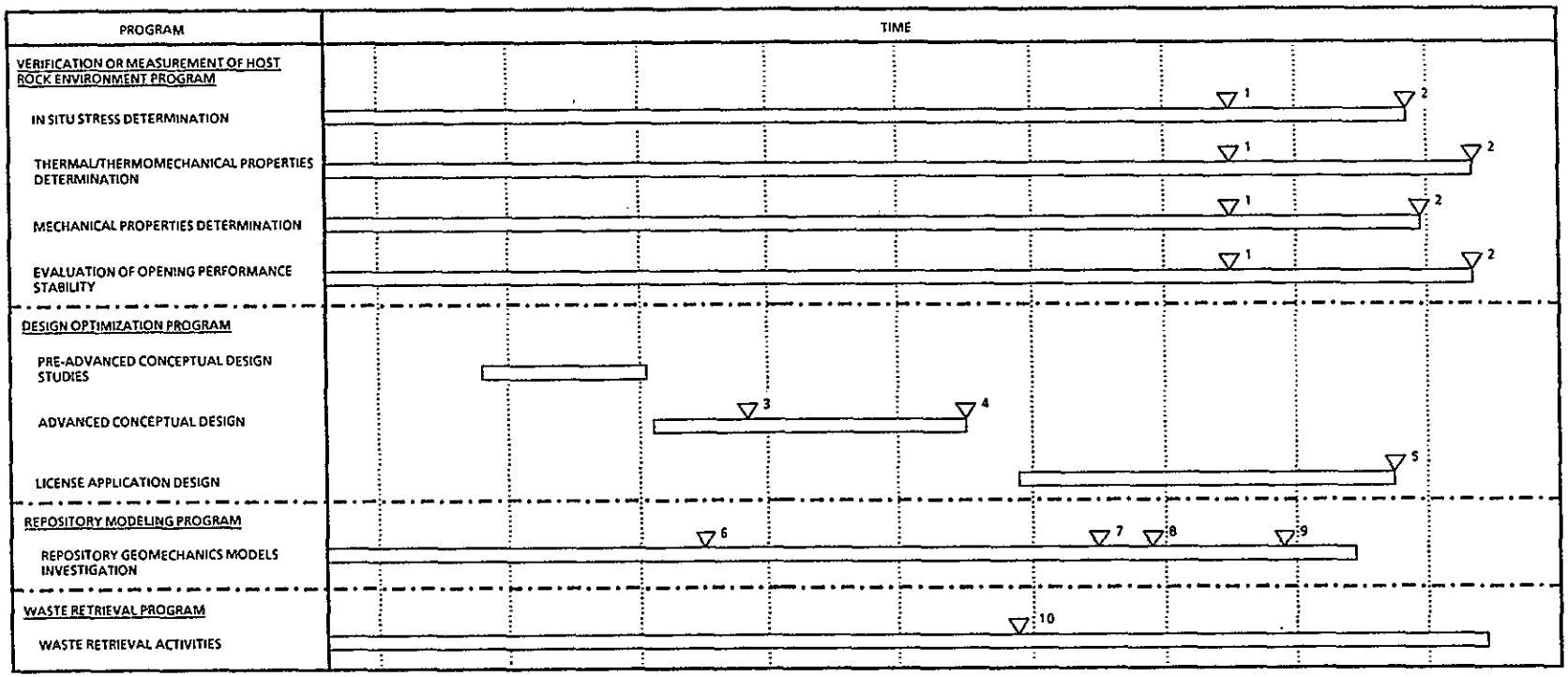

1 PROVIDE ROCK MECHANICS DATA FOR DRAFT ENVIRONMENTAL IMPACT STATEMENT AND PERFORMANCE ASSESSMENT ANALYSIS.

2 PROVIDE ROCK MECHANICS DATA FOR SITE DESCRIPTION AND LICENSE APPLICATION.

3 COMPLETE DESIGN TRADE-OFF STUDIES.

4 ACD REPORT ISSUED FOR APPROVAL

5 LAD REPORT ISSUED FOR APPROVAL

6 PROVIDE GEOMECHANICS MATERIAL MODEL FOR ACD ANALYSES.

7 OBTAIN DATA FROM EXPLORATORY SHAFT CONSTRUCTION

8 PROVIDE GEOMECHANICS MATERIAL MODEL FOR ACD ANALYSES.

9 OBTAIN RESULTS FROM EXPLORATORY SHAFT TESTS.

10 INPUT RESULTS FROM WASTE RETRIEVAL TESTING TO LAD.

ACD = ADVANCED CONCEPTUAL DESIGN
LAD = LICENSE APPLICATION DESIGN

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Figure 8.5-4. Repository program schedule.

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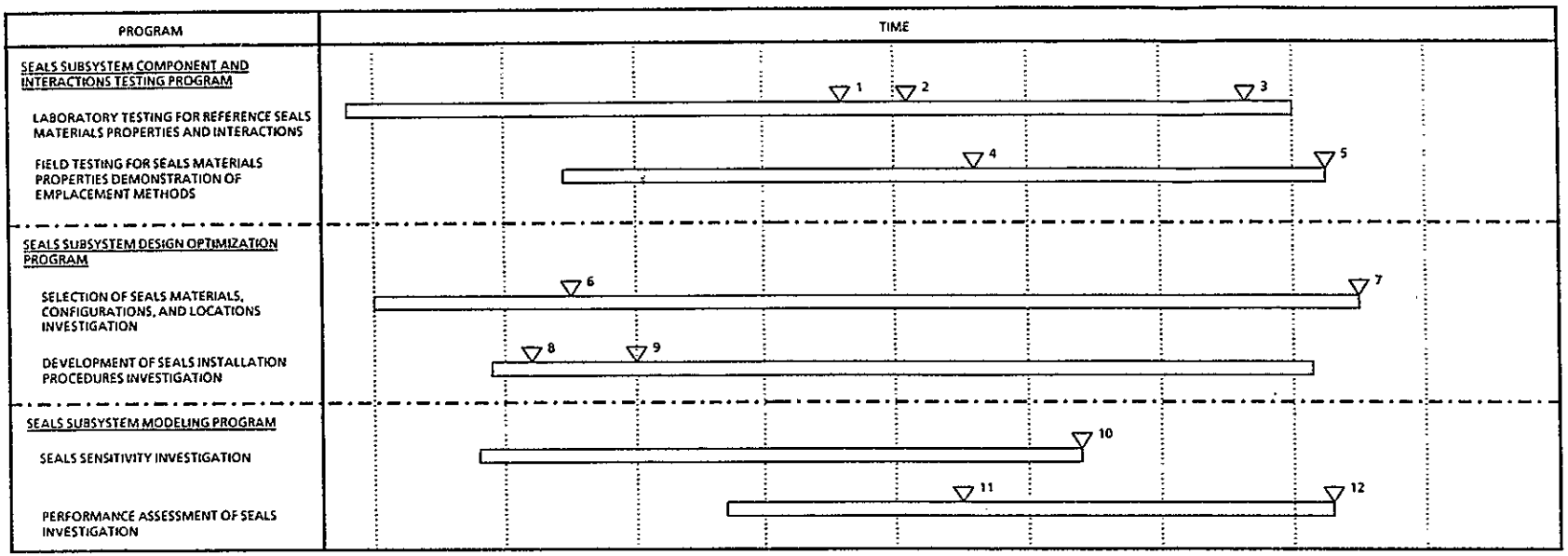

1 COMPLETE INSTALLATION OF EXPLORATORY SHAFT LINER AND GROUT.
2 COMPLETE INTERFACE FLOW TESTING FOR PERFORMANCE ASSESSMENT MODEL DEVELOPMENT FOR LAD.
3 COMPLETE STUDIES OF LONG-TERM STABILITY OF SEAL MATERIALS FOR INPUT TO LICENSE APPLICATION.
4 COMPLETE FIELD TESTING OF DRIFT AND BOREHOLE SEALS FOR LAD
5 COMPLETE STUDIES TO SUPPORT PERFORMANCE CONFIRMATION TEST PROGRAM
6 COMPLETE STUDIES OF SUBSURFACE BOREHOLE SEALING AND DRIFT SEAL INSTALLATION FOR FIELD TESTING
7 COMPLETE SEAL DESIGN STUDIES FOR LICENSE APPLICATION.
8 COMPLETE STUDIES OF SUBSURFACE BOREHOLE SEAL INSTALLATION METHODS FOR FIELD TESTING
9 COMPLETE STUDIES OF DRIFT SEAL INSTALLATION METHODS FOR FIELD TESTING
10 COMPLETE DEVELOPMENT OF MODELS FOR SEALS PERFORMANCE ASSESSMENT
11 COMPLETE PERFORMANCE ANALYSIS OF SEALS DESIGNS FOR ADVANCED CONCEPTUAL DESIGN
12 COMPLETE PERFORMANCE ANALYSIS OF SEALS DESIGNS FOR LAD.

LAD = LICENSE APPLICATION DESIGN

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Figure 8.5-5. Seals program major schedule.

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8.5.4 WASTE PACKAGE PROGRAM ACTIVITIES

The investigation-level schedules contained in the various subsections of Section 8.3.4 have been summarized and are presented in Figure 8.5-6. The schedule includes the specific programs for waste package environment, waste package components and interactions, and waste package design development that make up the waste package portion of the total program. Each specific program is supported by the individual investigation-level schedules taken from Section 8.3.4.

In addition to the relative schedule relations between investigations, certain key major events have been identified as appropriate to define controlling interrelationships between programs.

8.5.5 PROJECT MAJOR DECISION POINTS

Project logic is the definition of the planning strategy in terms of activities to be accomplished, sequencing their performance, and constraints on their start and (or) completion. Logic diagrams are based on requirements and priorities, and are the basis for development of the remainder of the planning process; namely, work plans and associated resource commitments, schedules, and budgets.

A generalized logic diagram, emphasizing the major decision points for the BWIP, is depicted in flow chart form in Figure 8.5-7. The major decision points are further identified in Table 8.5-1. When a decision point is reached, a choice must be made between two or more alternatives and is based on whether specific performance criteria are met. If the performance criteria are not met, some of the alternative courses of action that could be taken are listed below:

- Revise data collection program.
- Revise design program.
- Reallocate performance goals within the engineered system.
- Disqualify the site.

If the performance criteria are met, work will proceed as planned.

Table 8.5-1 includes a current assessment of the most likely outcome of the major decisions to be made. The program is being planned around these outcomes. If the actual decision-making process conducted at appropriate times indicates some other course of action is required, the program will be modified as necessary.

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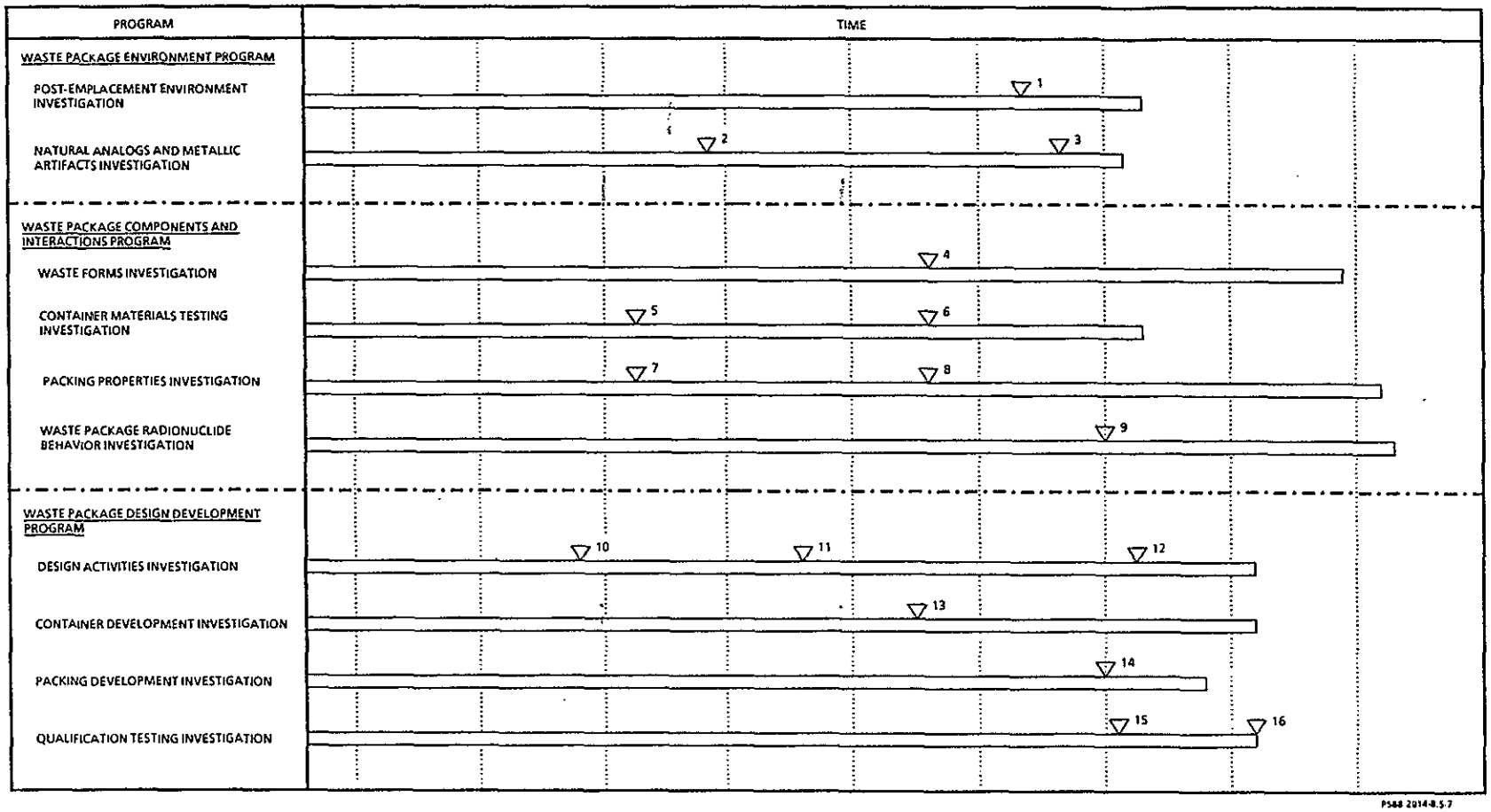

Figure 8.5-6. Waste package program schedule. (sheet 1 of 2)

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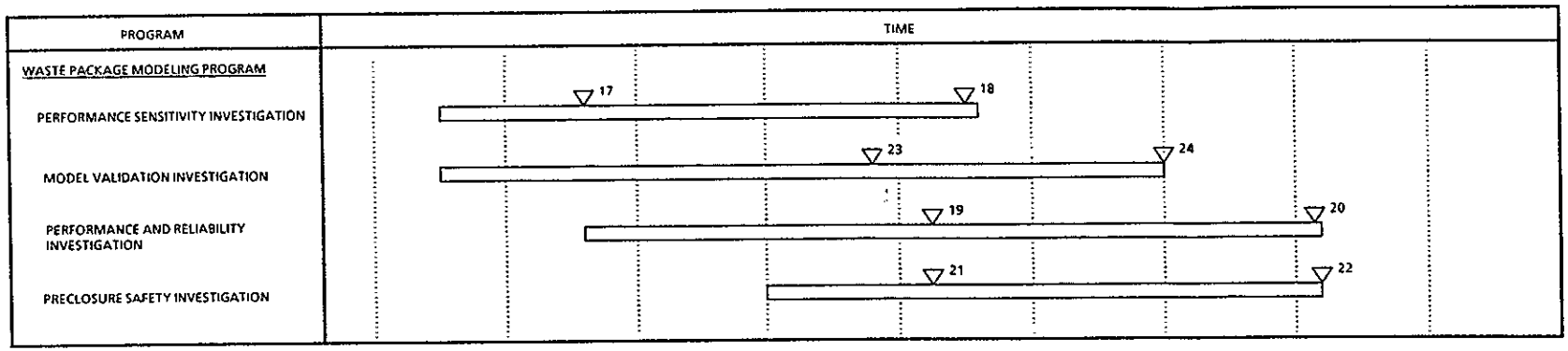

1 COMPLETE ENVIRONMENTAL ANALYSES TO SUPPORT LAD AND THE WASTE PACKAGE SCENARIO DOCUMENT
2 FINAL EVALUATION OF THE SIGNIFICANCE OF METALLIC ARTIFACTS.
3 FINAL EVALUATION OF NATURAL ANALOG EVIDENCE OF THE PERSISTENCE OF SECONDARY MINERALS.
4 BASELINE WASTE FORMS DATA TO LAD
5 RECOMMENDATION FOR REFERENCE AND ALTERNATE CONTAINER MATERIAL.
6 RECOMMENDATION FOR FINAL REFERENCE CONTAINER MATERIAL.
7 RECOMMENDATION FOR REFERENCE AND ALTERNATE PACKING MATERIAL.
8 RECOMMENDATION FOR FINAL REFERENCE PACKING MATERIAL.
9 PROVIDE RADIONUCLIDE SOURCE TERM DATA FOR PERFORMANCE AND RELIABILITY ANALYSES.
10 COMPLETE PRE-ACD STUDIES
11 COMPELTE ACD DESIGN ACTIVITY.
12 PROVIDE INDEPENDENT DESIGN AND RELIABILITY REPORTS FOR LAD.
13 FINAL SELECTION OF CONTAINER CONCEPT
14 ISSUE PACKING MATERIAL SPECIFICATIONS.
15 PROVIDE IN SITU TEST PLAN TO LAD FINAL REPORT
16 COMPLETE DATA INPUT TO VALIDATE WASTE PACKAGE PERFORMANCE AND RELIABILITY ANALYSIS.
17 COMPLETE WASTE PACKAGE PERFORMANCE SENSITIVITY FOR ACD
18 COMPLETE WASTE PACKAGE PERFORMANCE SENSITIVITY FOR LAD
19 COMPLETE WASTE PACKAGE PERFORMANCE AND RELIABILITY FOR ACD
20 COMPLETE WASTE PACKAGE PERFORMANCE AND RELIABILITY FOR LAD.
21 INPUT IMPACT STRESS/FRACTURE ANALYSIS TO ACD.
22 INPUT IMPACT STRESS/FRACTURE ANALYSIS TO LAD.
23 COMPLETE FINAL INTERNAL DEVELOPMENT REVIEWS
24 REPORT ON MODEL VALIDATION FOR LAD

ACD = ADVANCED CONCEPTUAL DESIGN
LAD = LICENSE APPLICATION DESIGN

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Figure 8.5-6. Waste package program schedule. (sheet 2 of 2)

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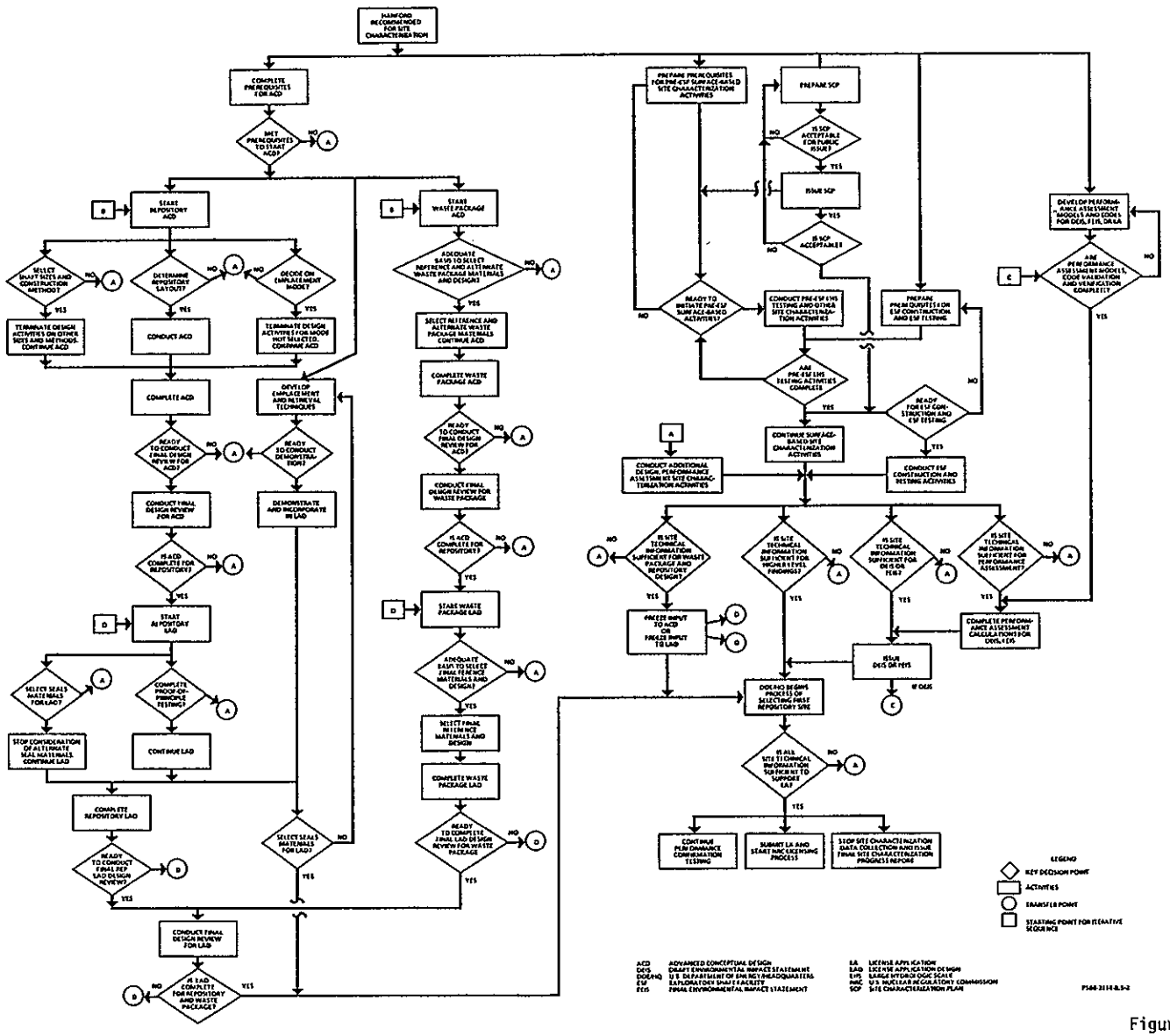

Figure 8.5-7. Project decision logic.

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Table 8.5-1. Project decisions (sheet 1 of 2)

Decision point	Likely outcome
Is the Site Characterization Plan ready for public issue?	Issue Site Characterization Plan.
Is the Site Characterization Plan acceptable?	Start site characterization.
Have all prerequisites been met to start waste package advanced conceptual design?	Conduct waste package advanced conceptual design.
Have all prerequisites been met to start repository advanced conceptual design?	Conduct repository advanced conceptual design.
Is project ready to initiate pre-Exploratory Shaft Facility surface-based activities?	Conduct pre-Exploratory Shaft Facility large-scale hydraulic stress testing and other site characterization activities.
Are pre-Exploratory Shaft Facility large-scale hydraulic stress testing activities complete?	Continue surface-based site characterization activities.
Is the project ready for Exploratory Shaft Facility construction and testing?	Conduct Exploratory Shaft Facility construction and testing activities.
Can the decision be made on shaft sizes and construction methods?	Terminate design activities on other shaft sizes and construction methods. Continue advanced conceptual design.
Can the decision on the repository layout be made?	Stop consideration of alternative layouts. Continue advanced conceptual design.
Can the decision on the waste emplacement mode be made?	Terminate design activities for the waste emplacement modes not selected. Continue advanced conceptual design.
Is there an adequate basis to select reference and alternate waste package materials and designs?	Select reference and alternate waste package materials and designs. Continue advanced conceptual design.
Is the waste package advanced conceptual design adequate and ready for final review?	Conduct final design review for the waste package advanced conceptual design.
Is the repository advanced conceptual design adequate and ready for final review?	Conduct final design review for the repository advanced conceptual design.
Is the waste package advanced conceptual design complete?	Release waste package advanced conceptual design and start license application design.
Is the repository advanced conceptual design complete?	Release repository advanced conceptual design and start license application design.
Is the technical basis adequate for selection of final reference waste package materials and design?	Select final reference waste package materials and design.

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Table 8.5-1. Project decisions (sheet 2 of 2)

Decision point	Likely outcome
Can the reference sealing material for license application design be selected?	Stop consideration of alternate materials. Continue license application design.
Is site characterization sufficient for repository design?	Continue license application design.
Is the project ready to demonstrate waste emplacement and retrieval technologies?	Demonstrate technologies and incorporate into license application design.
Are performance assessment models, codes, validation, and verification complete?	Complete performance assessment calculations for draft and final environmental impact statements.
Is site technical information sufficient for waste package and repository design?	Freeze input to advanced conceptual design; continue data collection for license application design or freeze input to license application design.
Is the project ready to conduct the final design review for the waste package license application design?	Conduct final design review for waste package license application design.
Is the project ready to conduct the final design review for the repository?	Conduct final design review for repository license application design.
Is the license application design complete for the waste package and repository?	Process begins to select the first repository.
Can the proof-of-principle testing of retrievability be completed?	Conduct tests and provide report in support of license application.
Is site technical information sufficient for performance assessment calculations?	Complete performance assessment calculations for draft and final environmental impact statements.
Is site technical information sufficient for the draft and final environmental impact statements?	Complete and issue draft and final environmental impact statements.
Is site technical information sufficient to support higher level findings on siting guidelines?	DOE begins process to select the first repository.
Is all technical information sufficient for license application?	Continue performance confirmation testing; complete license application and start U.S. Nuclear Regulatory Commission licensing process; stop site characterization data collection and issue final site characterization plan progress report.

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8.5.6 SUMMARY SCHEDULE

Figure 8.5-8 is a summary schedule for the site characterization phase of the BWIP. The schedule includes major programmatic milestones described in Table 8.5-2. The summary schedule should be viewed as an aid to understanding the overall structure of the site characterization phase. Specific information pertaining to individual programs should be obtained from other schedules in this chapter or in Chapter 8.3.

8.5.7 REFERENCES

DOE, 1987. General Guidelines for the Recommendation of Site for Nuclear Waste Repositories, Title 10, Code of Federal Regulations, Part 960, U.S. Department of Energy, Washington, D.C.

NWPA, 1983. Nuclear Waste Policy Act of 1982, Public Law 97-425, 96 Stat. 2201, 42 USC 10101.

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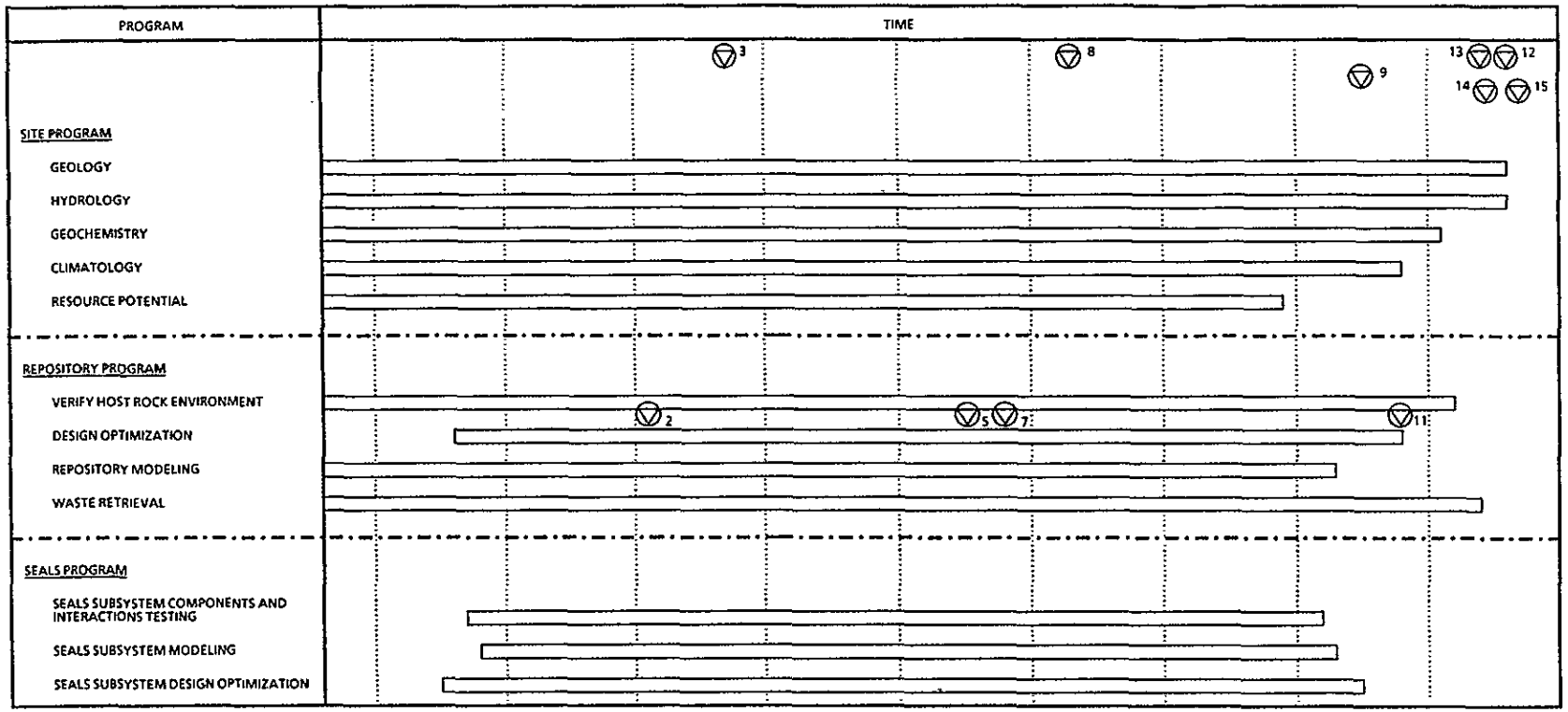

Figure 8.5-8. Project summary schedule. (sheet 1 of 2)

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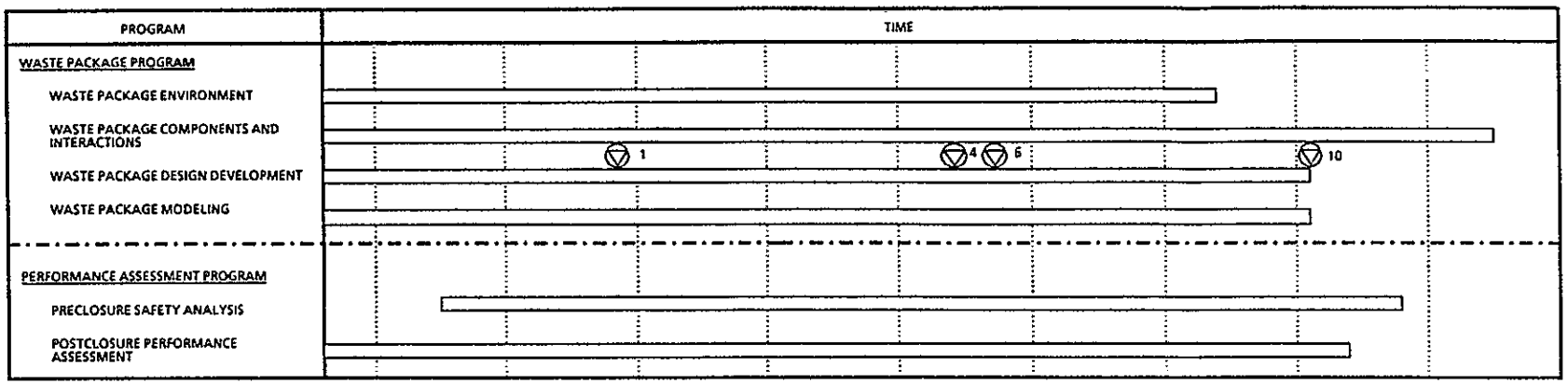

NOTE: AN EXPLANATION OF MILESTONE NUMBERS IS GIVEN IN TABLE 8.5-2. RELATIVE LOCATIONS OF MILESTONES REFLECT CURRENT PLANNING AND DO NOT NECESSARILY CORRESPOND TO THE DATA SEQUENCE IN TABLE 8.5-2 PS88-2014-8.5-8

Figure 8.5-8. Project summary schedule. (sheet 2 of 2)

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Table 8.5-2. Major Project Mission Plan Amendment*

Milestone No.	Item	Scheduled date
1.	Start waste package advanced conceptual design	October 1989
2.	Start repository advanced conceptual design	October 1989
3.	Start ES-1 construction	June 1989
4.	Complete waste package advanced conceptual design	January 1992
5.	Complete repository advanced conceptual design	January 1992
6.	Start waste package license application design	January 1992
7.	Start repository license application design	January 1992
8.	Connect shafts	January 1992
9.	Issue draft environmental impact statement	October 1993
10.	Complete waste package license application design	January 1994
11.	Complete repository license application design	July 1994
12.	Issue final environmental impact statement	October 1994
13.	Issue site selection report to President	November 1994
14.	Issue record of decision	November 1994
15.	Submit license application to U.S. Nuclear Regulatory Commission	January 1995

*The major project milestones in existence when the Mission Plan Amendment was issued in June 1987 are presented in this table. These milestones are under review to consider progress since the Mission Plan Amendment was issued and to review availability of resources needed to implement project plans. PST88-2014-8.5-2

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SITE CHARACTERIZATION PLAN

Chapter 8 - SITE CHARACTERIZATION PROGRAM

Section 8.6 Quality Assurance Program

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8.6 QUALITY ASSURANCE PROGRAM

Section 8.6 of the Site Characterization Plan for the Basalt Waste Isolation Project (BWIP) describes the quality assurance program that will ensure the quality of work and activities conducted by the U.S. Department of Energy-Richland Operations Office (DOE-RL) and BWIP participant contractors during the site characterization phase of the BWIP. Site characterization, which commenced on May 28, 1986, involves the performance of laboratory and field investigations involving various technical areas such as geology, hydrology, seismology, geophysics, geochemistry, and rock mechanics (all of which are generally considered part of geotechnical studies or investigations). In addition, waste package testing and conceptual design activities are to be performed, including development of performance requirements for repository system components. Information gathered and data collected and analyzed will be used to support a license application to the U.S. Nuclear Regulatory Commission (NRC) for the construction and operation of a geologic repository to be used for permanent disposal of high-level nuclear wastes. In conformance with regulatory requirements, the DOE-RL will implement a quality assurance program to provide confidence in the work performed during development of the repository, including information developed in support of licensing proceedings.

Quality assurance consists of all planned and systematic actions necessary to ensure that the geologic repository and subsystems or components will perform satisfactorily. Quality assurance includes quality control. Quality control comprises those quality assurance actions related to the physical characteristics of a material, structure, component, or system and provides a means to control the quality of the material, structure, component, or system to predetermined requirements. The quality assurance program applies to all systems, structures, and components of the proposed repository, its design, the characterization of the site, and all related activities. These related activities include facility and equipment construction, facility operation, performance confirmation, permanent closure, and decontamination and dismantling of surface facilities.

The topics and order of presentation for this section are as follows:

- Section 8.6.1 contains a description of the BWIP philosophy on quality assurance and the DOE-RL BWIP Quality Assurance Plan (DOE-RL, 1987b), which implements this philosophy and provides guidance for the implementation of federally mandated quality assurance requirements.

- Section 8.6.2 contains a discussion of the origins of the quality assurance requirements and a summary of those requirements to be implemented during site characterization by the DOE-RL and the BWIP participant contractors.

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- Section 8.6.3 contains a description of the general organization of the BWIP, organization of project management, delegation of work, lines of communication, and quality assurance responsibilities for DOE-RL and BWIP participant contractors.

- Section 8.6.4 contains a description of the quality controls during site investigation, site characterization, repository design, and waste package design.

- Section 8.6.5 contains lists of the quality assurance administrative procedures that establish how the quality assurance programs of the DOE-RL and BWIP participant contractors will be implemented.

- Section 8.6.6 describes the detailed procedures generated by the DOE-RL and the BWIP participant contractors that provide for the application and implementation of quality assurance administrative procedural requirements to specific program areas.

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8.6.1 QUALITY ASSURANCE PLAN SUMMARY

An effective quality assurance program is required to be maintained by the BWIP management and staff for work and activities performed in support of the BWIP. The quality assurance program is planned, documented, and implemented to support activities affecting quality that occur as the BWIP moves through site exploration, site characterization, repository design, and possible repository site selection.

The assurance of quality is an interdisciplinary activity involving many organizational components and is not the sole domain of any one organization. It is the responsibility of both the DOE-RL staff and each BWIP participant contractor, in accordance with the federally mandated requirements, (1) to plan and perform activities affecting quality and (2) to develop and implement self-assessment activities ensuring compliance with those requirements.

The Quality Assurance Departments for the DOE-RL and each BWIP participant contractor performing work or activities for BWIP are responsible for describing, monitoring, and verifying satisfactory accomplishment of quality-affecting activities of the BWIP. This designated obligation does not, however, relieve the line organizations of responsibility for performing quality-related activities in accordance with federally mandated requirements and of ensuring compliance of quality-related activities with those requirements.

Based on the DOE-RL responsibility to assure, achieve, and verify the quality of items and activities associated with the BWIP site characterization and design, the DOE-RL has prepared the BWIP Quality Assurance Plan (DOE-RL, 1987b) to ensure a systematically controlled approach to the BWIP work. This plan describes how federally mandated quality assurance program requirements are to be translated into plans and procedures for implementation. The plan

describes quality assurance administrative and implementing procedures, identifies groups responsible for implementation of procedural requirements, and describes the interaction of those groups to accomplish quality requirements.

The DOE-RL BWIP Quality Assurance Plan is the top BWIP quality assurance planning document. It is intended to implement the plan specified by DOE Order 5700.6B (DOE, 1986c), the Department of Energy Quality Assurance Management Policies and Requirements (DOE, 1985), the Quality Assurance Plan for High-Level Waste Repositories (DOE, 1986c), and DOE-RL Order 5700.1B (DOE-RL, 1986c). This quality assurance plan establishes controls necessary to satisfy federally mandated quality assurance requirements applicable to BWIP work and activities. Compliance with applicable provisions of this quality assurance plan by the DOE-RL Office of Commercial Nuclear Waste and all BWIP participant contractors is mandatory. Quality Assurance plans prepared for BWIP are as follows:

- The U.S. Department of Energy-Richland Operations Office.

  U.S. Department of Energy Quality Assurance Plan for the Basalt Waste Isolation Project (DOE-RL 1987b)

- Westinghouse Hanford Company, Civilian Waste Management Division, Basalt Waste Isolation Project (integrating contractor).

  Westinghouse Hanford Company, Civilian Waste Management Division, Basalt Waste Isolation Project Quality Assurance Program Requirements Manual (WHC, 1987b)

- Morrison-Knudsen (construction manager).

  Quality Assurance Manual for Contract No. DE-AC06-83RL10343, Basalt Waste Isolation Project

- Kaiser Engineers, Inc./Parsons Brinkerhoff Quade & Douglas, Inc. (architect-engineer).

  Project Quality Assurance Plan Basalt Waste Isolation Project

The assistant manager of the DOE-RL Office of Commercial Nuclear Waste (Fig. 8.6-1) is the overall project manager and is responsible for the direction, content, and effective implementation of quality requirements governing all BWIP activities. This responsibility includes coordinating and verifying implementation of quality assurance programs by all BWIP participant contractors. Certain BWIP work and the implementation of quality assurance program requirements applicable to that work have been delegated to the BWIP participant contractors. The DOE-RL Office of Commercial Nuclear Waste, however, retains ultimate responsibility for delegated functions and activities, including quality, and for ensuring that all BWIP participant contractors effectively respond to applicable quality requirements. The

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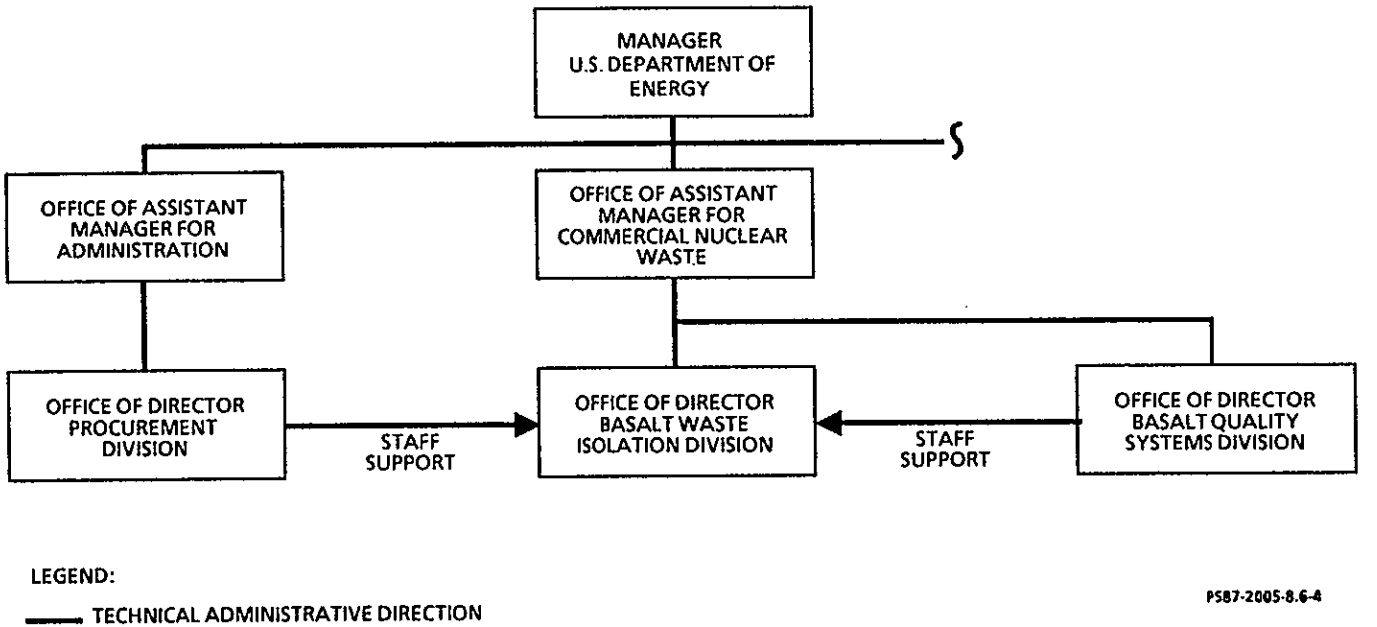

Figure 8.6-1. U.S. Department of Energy-Richland Operations Office Basalt Waste Isolation Project organization chart.

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implementing responsibilities of the DOE-RL and three BWIP participant contractors (the integrating contractor, Westinghouse Hanford Company, Civilian Waste Management Division (Westinghouse BWIP), the construction manager (Morrison-Knudsen Company, Inc.), and the architect-engineer (Kaiser Engineers, Inc./Parsons, Brinckerhoff, Quade & Douglas, Inc.)) are described in Section 8.6.3. The hierarchy relationship of the various quality assurance documents is depicted in Figure 8.6-2.

Based on the quality requirements of the DOE-RL BWIP Quality Assurance Plan (DOE-RL, 1987b) and project management directives issued by the DOE-RL to specify how certain management activities are to be conducted, each BWIP participant contractor will establish a quality assurance program. These programs will consist of required plans, quality assurance administrative procedures that provide instruction for implementation of applicable requirements, and detailed technical implementing procedures that (1) incorporate the applicable requirements specified in the administrative quality assurance procedures and (2) contain instructions for the performance of work and activities such as design, testing, etc.

The DOE-RL Office of Commercial Nuclear Waste is responsible for the approval of quality assurance plans and quality assurance administrative procedures prepared by the integrating contractor, the construction manager, and the architect-engineer. Quality Assurance plans prepared by the BWIP participant contractors are as follows:

- The U.S. Department of Energy-Richland Operations Office.

  U.S. Department of Energy Quality Assurance Plan for the Basalt Waste Isolation Project (DOE-RL 1987b)

- Westinghouse Hanford Company, Civilian Waste Management Division, Basalt Waste Isolation Project (integrating contractor).

  Westinghouse Hanford Company, Civilian Waste Management Division, Basalt Waste Isolation Project Quality Assurance Program Requirements Manual (WHC, 1987b)

- Morrison-Knudsen (construction manager).

  Quality Assurance Manual for Contract No. DE-AC06-83RL10343, Basalt Waste Isolation Project

- Kaiser Engineers, Inc./Parsons Brinkerhoff Quade & Douglas, Inc. (architect-engineer).

  Project Quality Assurance Plan Basalt Waste Isolation Project

Each participant contractor is responsible for review and approval of the quality assurance program descriptions and quality assurance administrative procedures prepared by its subcontractors.

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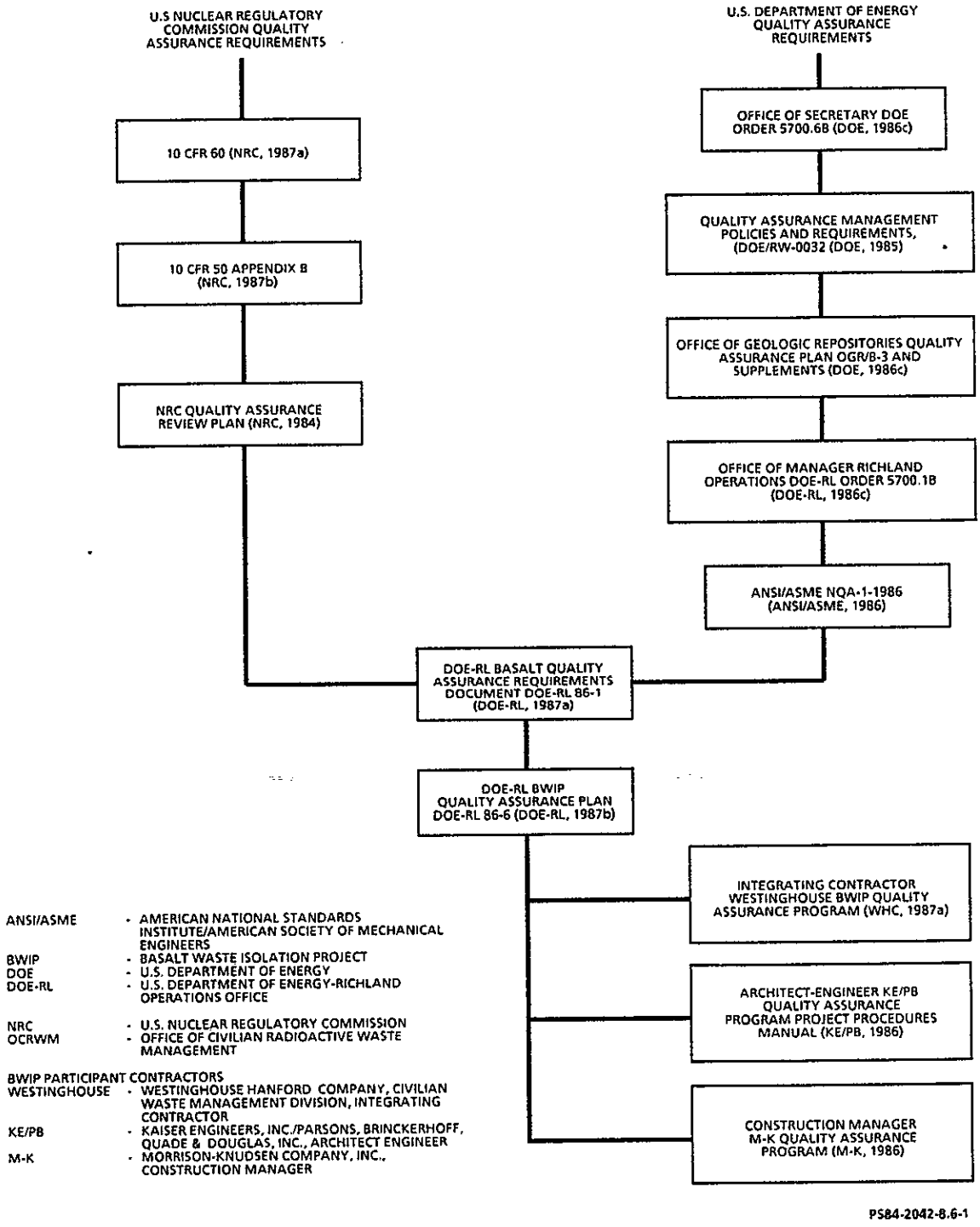

Figure 8.6-2. Quality assurance documents hierarchy.

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The quality assurance plan for each BWIP participant contractor includes a policy statement signed by the senior project officer of that participant contractor, mandating compliance with that contractor's approved quality assurance plan and procedures for work within the scope of the BWIP.

The quality assurance program consists primarily of controls implemented by the participants' line organizations performing technical activities. The extent of these controls is established by a joint effort of the technical and quality assurance organizations. The DOE project management responsibility requires establishment of project objectives, overview of participants' management, and verification that participants implement planned controls effectively. The DOE-RL Office of Commercial Nuclear Waste technical personnel, in the course of evaluating contractor technical progress, must be satisfied that applicable controls have been and are being exercised effectively (i.e., not only that the technical approach is valid, but also that it is based on properly controlled supporting data and analyses).

The project overview of contractor performance by the DOE-RL Office of Commercial Nuclear Waste (Assistant Manager) therefore includes (1) Basalt Quality Systems Division verification that contractors are effectively implementing the control systems that constitute the required project quality assurance program and (2) Basalt Waste Isolation Division evaluation of the technical effectiveness of those controls (Fig. 8.6-3).

Certain activities performed by the DOE-RL Office of Commercial Nuclear Waste personnel directly affect technical outcome of the project (i.e., selecting from technical alternatives, approval of contractor technical recommendations, direction with respect to approaches, etc.). Quality assurance controls affecting these activities are specified in DOE-RL Office of Commercial Nuclear Waste procedures. The Basalt Quality Systems Division verifies effective implementation of specified controls by quality assurance audit and surveillance.

At intervals determined by the Project Manager of the BWIP, but not exceeding 1 yr, a management team assesses effectiveness of the overall BWIP quality assurance program's implementation. The assessment team's structure and the mechanics of the assessment process are addressed by an approved procedure. These management assessments are in addition to quality assurance audits and surveillances performed by the Basalt Quality Systems Division.

In addition, each BWIP participant contractor is required to perform management assessments to determine the effectiveness of its quality assurance program. Such assessments are required to include regular contact with program status through reports, meetings, and audits, as well as performance of a procedurally controlled, preplanned, documented management assessment, with corrective action identified and tracked. These management assessments are in addition to quality assurance audits and surveillances performed by the participant contractor's Quality Assurance Organization.

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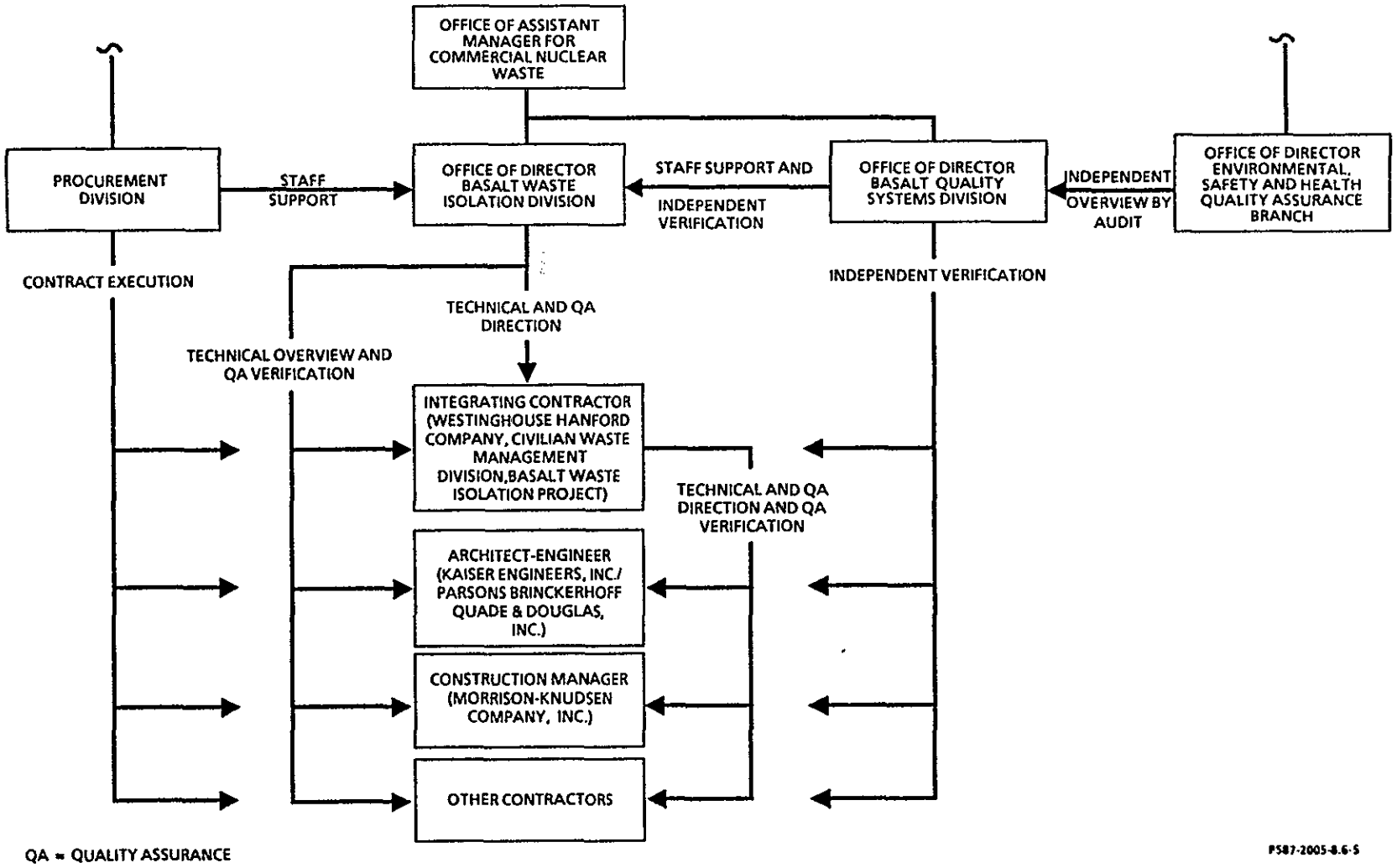

Figure 8.6-3. Basalt Waste Isolation Project organization.

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Disputes involving differences in interpretation of quality assurance requirements between quality assurance personnel and other department personnel anywhere in the BWIP are required to be escalated to a level where agreement can be reached, up to and including the U.S. Department of Energy-Headquarters (DOE-HQ) Office of Civilian Radioactive Waste Management (OCRWM).

8.6.2 QUALITY ASSURANCE PROGRAM REQUIREMENTS

The quality assurance requirements for the BWIP originate from two main sources: the NRC and the U.S. Department of Energy (DOE) (see Fig. 8.6-2).

The NRC, by way of 10 CFR 60 Subpart G (NRC, 1987a), has made the quality provisions of 10 CFR 50, Appendix B (NRC, 1987b), mandatory for all systems, structures, and components designated as "important to safety" or "important to waste isolation" and activities related thereto. In addition, the NRC published the NRC Review Plan: Quality Assurance Programs for Site Characterization of High-Level Nuclear Waste Repositories (NRC, 1984). This document has two purposes: (1) to define the criteria and methods for NRC review of the quality assurance program for site characterization during the prelicensing phase and (2) to provide guidance for establishing an acceptable program for items designated as "important to safety" or "important to waste isolation" and activities related thereto.

The Office of Geologic Repositories Quality Assurance Plan for High-Level Waste Repositories (DOE 1986d), DOE Order 5700.6B (DOE, 1986c), and DOE-RL Order 5700.1A (DOE-RL, 1983) provide that the basic and supplementary requirements included in the American National Standards Institute/American Society of Mechanical Engineers (ANSI/ASME) NQA-1-1986 (ANSI/ASME, 1986) are the preferred standards for the implementation of quality assurance programs for DOE projects. The NQA-1-1986 requirements (ANSI/ASME, 1986) also provide an adequate basis for interpreting the pertinent quality assurance requirements of 10 CFR 50, Appendix B (NRC, 1987b), for the establishment and execution of quality assurance programs during the design and construction phases of nuclear facilities. For site characterization activities, however, the additional requirements of the NRC Review Plan (NRC, 1984) are incorporated for items important to safety and important to waste isolation and activities related thereto. The requirements of ANSI/ASME Quality Assurance Program Requirements (ANSI/ASME, 1986) shall be evaluated to assure that its provisions are applicable to site characterization activities as opposed to construction activities and do not contradict the requirements of the NRC Review Plan (NRC, 1984).

In addition, where the Office of Geologic Repositories (Fig. 8.6-4) has determined it necessary for each project office to perform certain quality-related activities (e.g., peer review, graded quality assurance) in a uniform manner, supplements to the Office of Geologic Repositories Quality Assurance Plan for High-Level Waste Repositories (DOE, 1986d) have been issued.

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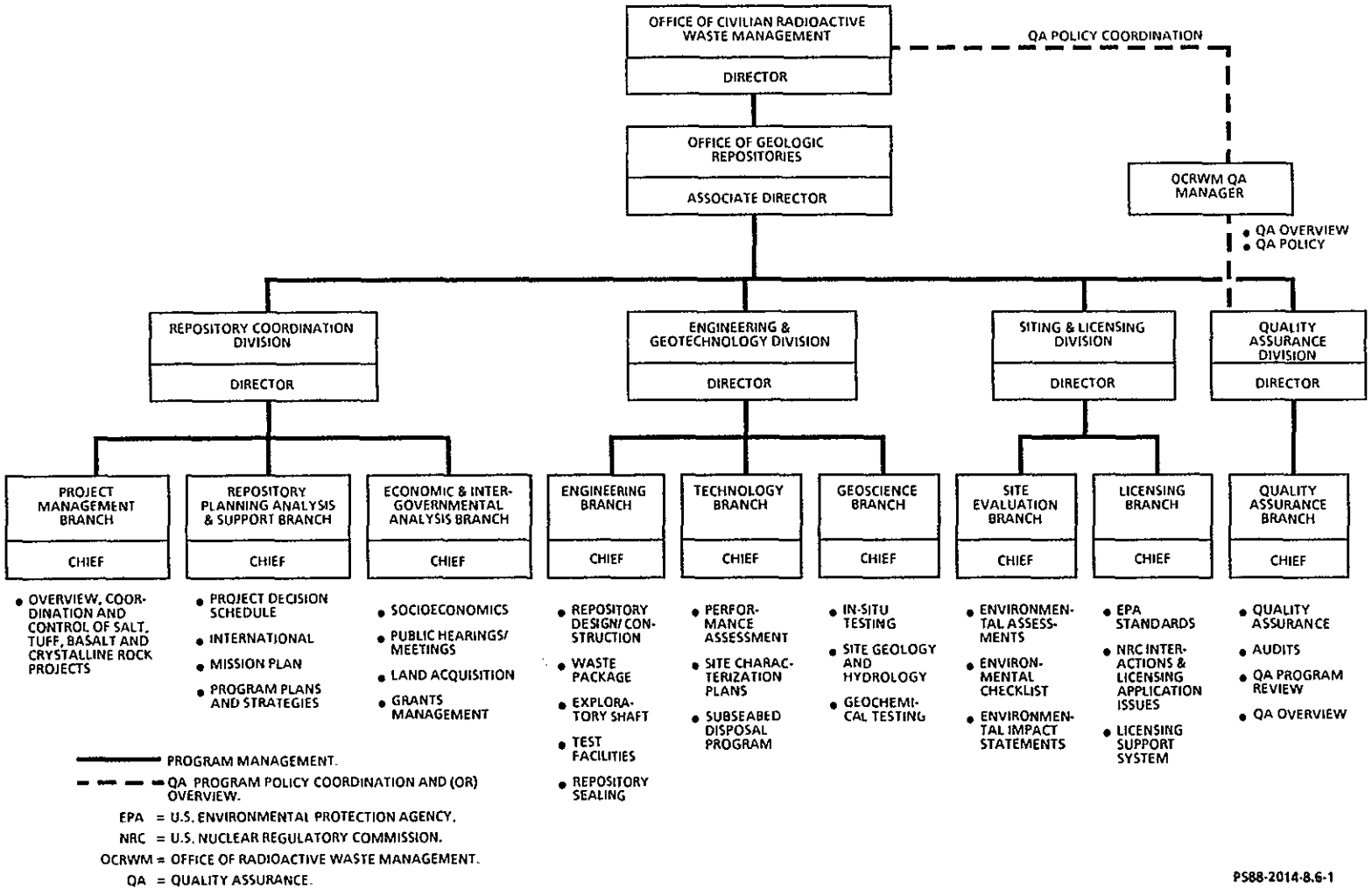

Figure 8.6-4. Office of Geologic Repositories organization chart.

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To ensure uniform and acceptable interpretation of the requirements for quality assurance, the Basalt Quality Assurance Requirements Document (BQARD) (DOE-RL, 1987a) was prepared by the DOE-RL for the BWIP site characterization activities. The purpose of this document is to provide BWIP participant contractors with interpretations of the quality assurance requirements appropriate for site characterization, design, and license application phases of an NRC-licensed geologic repository. The BQARD consolidates all requirements of the above DOE and NRC documents into a single, site-specific document that provides clear interpretations of the federally mandated quality assurance requirements as they apply to geologic repository work related to items designated as important to safety or important to waste isolation.

The BQARD is divided into 18 sections that are titled and organized to coincide with the format and content of the 18 criteria of 10 CFR 50, Appendix B (NRC, 1987b), the NRC Review Plan (NRC, 1984), and the Quality Assurance Program Requirements for Nuclear Facilities (ANSI/ASME, 1986). The method of implementing these requirements is provided in the BWIP Quality Assurance Plan (DOE-RL, 1987b). A brief description of the major elements of the BWIP quality assurance program follows along with a method of implementation of each section of the BQARD for work or activities related to items designated as important to safety or important to waste isolation and other quality levels (Section 8.6.4.2).

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8.6.2.1 Criterion 1.0, Organization

This criterion requires documentation of organizational structures, levels of authority, functional responsibilities, and lines of communication for activities affecting quality. The description is provided in Section 8.6.3.

8.6.2.2 Criterion 2.0, Quality Assurance Program

This criterion requires the establishment of a documented quality assurance program that is planned, implemented, and maintained and that identifies the activities and items to which it applies. The program must provide for the indoctrination and training necessary to ensure that suitable proficiency is achieved and maintained by those personnel performing quality-related work. Management must regularly assess the adequacy of the program. The description of the quality assurance program is provided in this section.

8.6.2.3 Criterion 3.0, Design Control

This criterion provides for the control of design, design information, and design activities for the BWIP. The terms design, design information, and design activities as used in this section need to be defined. The term

"design" refers to specifications, drawings, design criteria, and component performance requirements for the natural and engineered components of the repository system. It includes designs at each stage of design development (i.e., from conceptual design to final design). "Design information" and "design activities" refer to data collection and analysis activities used in supporting design development and verification. These terms include general plans and detailed procedures for data collection and analysis and related information (e.g., test results and analysis). Data analysis includes not only the initial step of data reduction but also broad-level systems analysis (e.g., performance assessments), which integrates many other data and analyses of individual parameters.

The BWIP design controls include not only controls traditionally used to ensure correct translation of design inputs into designs but also controls to ensure adequacy and validity of site characterization results and design bases. Plans and strategies, acquisition, reduction, analysis of data during site characterization, and subsequent system analyses are construed as activities that are governed by controls described in Sections 8.6.2.3.1 through 8.6.2.3.7.

The BWIP participant contractors shall include provisions in their design control procedures for (1) documenting design errors and deficiencies on discovery, (2) ensuring that resulting corrections are properly reflected across all affected design interfaces, and (3) verifying that design documents reflect as-built conditions documented for nonconformances that are dispositioned as "repair" or "accept-as-is."

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8.6.2.3.1 Computer software

Computer software for technical computer codes used in analyzing items important to safety or important to waste isolation is to be controlled by participant contractor procedures consistent with guidelines established in NUREG 0856 (NRC, 1986).

8.6.2.3.2 Application of design control to data acquisition

The processes of identifying data needs, planning data acquisition work and sequence, and experiment design (e.g., preparation of the necessary test procedures) for the BWIP are based on, and developed concurrently by, establishing (1) which of the physical characteristics of the repository site must be determined, (2) how, and in what sequence, this characterization is to be done, and (3) what processes of data acquisition best assure the validity

of data. Therefore, the activities of data acquisition (test) planning and data acquisition (text) procedure generation require the same generic controls that more conventional downstream design activities require.

While preparation, review, and approval of data acquisition planning and procedure generation are controlled under the design control provisions of the quality assurance program, actual performance of the experiments, measurement, collection, etc., for acquiring data is controlled under applicable provisions shown in Criterion 11.0.

A considerable body of data relevant to site characterization (e.g., geotechnical, climatological, etc.) was accumulated during activities pre-dating establishment of the BWIP and (or) data acquired without the current level of approved management controls in effect. The level of qualification of such existing data for site characterization purposes will be established on a case-by-case basis. Criteria for determining data qualification levels will be developed by the BWIP, with due regard to relevant NRC and (or) Office of Geologic Repositories guidance.

Reduction and analysis of data collected during BWIP site characterization, or of prior data that have since been qualified, will be performed under controls specified in approved participant procedures. Such procedures will provide, as appropriate to the nature of the data reduction and (or) analysis at issue, for the following:

- Documentation of assumptions, calculations, computer codes used, and intermediate results, as applicable.
- Independent review of the reduced data or completed analysis, to include consideration of appropriateness of assumptions and approaches, if applicable, and a check on the reasonableness of calculation results (using simplified alternate calculations if necessary).
- Peer review if the reduction or analysis of the approach or technique is unusual, controversial, or state of the art.
- Clear identification of results or conclusions requiring subsequent confirmation by additional exploration or research, or completion of ongoing work.
- Verification of effective implementation of applicable controls (by audit, surveillance, etc.).

Exploration or research results reported in the literature may be used as background, evidence of consensus, or explicit support for site characterization conclusions. When used in direct support of conclusions, such application will be controlled by participant procedures that provide criteria for such use.

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8.6.2.3.3 Design controls for site characterization studies and design of equipment, facility, waste form, and waste form packaging

Participant contractors responsible for strategy, test planning, test procedures, site characterization studies, or design of (1) facilities or equipment that could subsequently be used if the BWIP site is selected as a repository site, (2) equipment with characteristics that could affect validity of site characterization, or (3) conceptual designs on which site characterization approaches or analyses will be based, will perform such activities in accordance with approved procedures that provide the following controls:

- Traceable documentation of design inputs, including the rationale for design decisions.
- Documentation of design assumptions, including rationale.
- Approved computer software controls.
- Competent, independent review.
- Approval by designated authority.
- Independent design verification.
- Control of design interfaces.
- Control of design changes equivalent to the controls applied to original design.
- Review of design drawings, specification criteria, and analyses by personnel of the responsible quality assurance organization to ensure compliance with governing procedures and quality assurance program requirements.

Formal design review consists of critical appraisal of the design by independent, competent personnel having expertise in the disciplines or practices on which the design is based and in those related fields that may affect the ability of the design to perform its intended function. Individuals participating in design verification are expected to verify that the design adequately addresses limitations and effects associated with factors related to their fields of expertise.

Verification by testing is intended to establish the ability of some or all design features to perform the intended function(s) under the most adverse design conditions. In simulating design conditions, appropriate provisions shall be made to assess potential effects of simultaneous occurrences determined by safety analysis to be credible. Such occurrences arise when adverse conditions reinforce each other if they were to occur simultaneously

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(e.g., seismic events and outbreak of fire). Where testing reveals design or fabrication deficiencies, the testing shall be repeated after correction of the deficiency(ies).

Design calculations may be verified by use of alternate calculations. Such calculations may be made by simplified methods verifying that results of the previous calculations are reasonable.

Where all or portions of a design are verified by similarity to prior designs, verification shall establish the following:

- The conditions under which the prior design operated were the same as, or more severe than, relevant conditions in which the present design will operate.
- The prior design operated, or was tested under, the most adverse combination of design conditions applicable to the present design.
- The designer has determined and appropriately accounted for any deficiencies discovered during operation of the prior design.

8.6.2.3.4 Peer review

A peer review is a documented critical review performed by personnel who are independent of those who performed the work, but who have technical expertise in pertinent areas at least equivalent to those who performed the original work. Peer reviews are in depth, critical reviews and evaluations of documents, material, or data requiring interpretation or judgment to verify or validate assumptions, plans, results, or conclusions. When conclusions, material, or data contained in a report go beyond the existing state of the art, a peer review is necessary.

Peer reviews are not to be confused with technical reviews, which are documented, traceable reviews, critical reviews, analyses, and evaluations of documents, material, or data that require technical verification and (or) validation for applicability, correctness, adequacy, and completeness.

Peer reviews are required for activities that support a license application and involve use of data collection or analysis procedures and methods that are untried or beyond the state of the art or where detailed technical criteria and requirements do not exist or are being developed. Other instances where a peer review should be considered in lieu of a technical review include situations in which (1) analytical modeling techniques are (or will be) applied to a range of conditions outside of their normally accepted boundaries, (2) data collection results are not predictable with a high degree of certainty, (3) activities are not feasibly repeatable, or (4) data collection was performed prior to the establishment of formal quality assurance provisions, or if data were collected in nonconformance with established quality assurance provisions.

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8.6.2.3.4.1 Peer review group selection

Each organization responsible for establishing a peer review program shall document procedures that define the selection process for a peer review group. The peer review group shall be composed of individual(s) who have qualifications at least equivalent to those required for performance of the original work and who did not perform the work being reviewed. The peer reviewer's qualifications shall be documented and verified by the organization requesting the peer review.

8.6.2.3.4.2 Peer review performance

Peer reviews shall address the following areas as applicable:

- Validity of basic assumptions or functional requirements.
- Appropriateness of methodology.
- Logic of methodology.
- Verification of calculations or computer software.

Peer reviews shall be conducted in accordance with written procedures that shall address the following:

- The review process and reviewer responsibilities.
- Handling of comment resolution.
- Reporting minority positions.
- Involvement of the quality assurance organization.
- Changes to previously peer-reviewed documents.
- Review of revised documents.
- Records of the review.

Review of previously peer-reviewed documents shall be performed whenever the technical content or results presented in the documents are significantly revised.

8.6.2.3.4.3 Peer review records

Peer review records shall include the qualifications of the reviewers, results of the review, disposition of, or replies to, reviewer comments, and minority positions. The peer review records shall be retained commensurate with the retention requirements of the data or documents the records support.

8.6.2.3.5 Design changes

Design changes require technical controls commensurate with controls exercised on the original design, including review by the design organization responsible for the original design (unless otherwise specified by the DOE).

8.6.2.3.6 Design interfaces

Design interfaces are identified and controlled, and the design efforts are coordinated among the participating organizations. Interface controls include the assignment of responsibility and the establishment of procedures among participating design organizations for the review, approval, release, distribution, and revision of documents involving design interfaces.

Design information transmitted across interfaces is documented and controlled. Where it is necessary to initially transmit design information orally or by other informal means, the transmittal is confirmed promptly by a controlled document. The integrating contractor is responsible for assuring that such interfaces are clearly defined by those participants and that interfacing design organizations maintain up-to-date procedures for clear and timely communication across interfaces.

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8.6.2.3.7 Review plan

Each participant contractor is required to develop a general plan and continually update it to show the technical and readiness reviews that are to be accomplished for site characterization and design activities. The integrating contractor is responsible for obtaining and integrating the necessary information for this plan on a project-wide basis.

The DOE-RL Office of Commercial Nuclear Waste personnel exercise regular and frequent technical overview and quality verification within their areas of expertise over technical work being performed by project participants. Technical surveillance includes the following:

- Confirmation that approaches conform to recognized practice within the applicable disciplines or to practice evaluated and endorsed through the peer review process.
- Confirmation that in-process results reasonably proceed from the assumptions and approaches being used.
- Evaluation of technical effectiveness of controls applied to collection, reduction, and analysis of supporting data or studies.

Basalt Waste Isolation Division technical personnel will be involved in the peer review process in two ways. The cognizant Basalt Waste Isolation Division individual will participate in, or observe, selected peer reviews convened by BWIP participants. Any Basalt Waste Isolation Division technical individuals may initiate peer reviews if they have reason to believe BWIP work in their areas of expertise meets one or more of the peer review criteria.

Basalt Waste Isolation Division technical personnel review technical documents (e.g., test reports, analyses, reports of study results, etc.) for appropriateness of approach, reasonableness of conclusions, clarity, and

evidence of necessary supporting inputs. Such reviews and subsequent approval are to be accomplished prior to initiation of affected follow-on work unless provisional go-ahead is authorized explicitly on an exception basis.

Any member of the DOE-RL Office of Commercial Nuclear Waste staff may initiate a documented review meeting to resolve a concern. Typically, a documented review meeting is convened if a staff member feels that too many controversial issues have surfaced during a peer review or if a staff member has unresolved questions concerning technical or quality-related aspects of work after reviewing a document generated by one of the BWIP participant contractors.

8.6.2.4 Criterion 4.0, Procurement Document Controls

Procurement document controls in the BWIP are intended to ensure that the responsible participant contractor communicates needs and requirements clearly and accurately to the supplier. The BWIP participant contractors are required to establish and implement administrative procedures for the preparation and control of documents that specify technical and quality assurance requirements for purchased items or services. These procedures will include provisions and identify responsibilities for the following activities:

- Procurement planning.
- Preparation, review, approval, and control of procurement documents.
- Review of procurement documents by the participants' quality assurance personnel to determine that applicable regulatory requirements, design bases (where applicable), and other requirements are referenced or included in the procurement documents; that adequate accept (reject) criteria and plans for acceptance are included where appropriate; that an appropriate supplier quality assurance program has been specified; and that the procurement documents have been prepared, reviewed, and approved in accordance with the applicable procedure(s) (NRC, 1984).
- Bid evaluation, with participation by the initiator and (or) quality assurance (as applicable) for bids that restate or interpret technical and quality assurance requirements.
- Review of, and concurrence with, the supplier's quality assurance program prior to initiation of supplier work subject to program requirements.

For controls related to procurement of instrumentation or equipment used for data collection under conditions in which failure or malfunction during collection of data might not be detectable see Criterion 11.0, Section 8.6.2.11.

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The Westinghouse BWIP Quality Assurance Department will evaluate selected procurement document packages prepared by other BWIP participants during audits and surveillances of those participants' quality assurance program implementation. The Basalt Quality Systems Division will review selected procurement document packages prepared by BWIP participants, including those prepared by the integrating contractor during quality assurance audits and surveillances of BWIP activities.

8.6.2.5 Criterion 5.0, Instructions, Procedures, and Drawings

The BWIP activities are prescribed by, and performed in accordance with, written instructions, procedures, specifications, or drawings appropriate to the work. Such procedures, instructions, or drawings are to be reviewed for accuracy and adequacy by personnel who are both competent in the subject matter addressed and who are independent of the preparation of the document being reviewed.

Administrative procedures are documents that define management controls and control systems, establish responsibilities and authorities for exercising them, and specify the approved overall methodology. The BWIP is governed by two basic categories of administrative procedures: (1) procedures that define and direct operation of the BWIP management system, covering such areas as the work breakdown system and the various project baselines, and (2) procedures that define and direct controls and control systems making up the BWIP quality assurance program. Requirements of this section apply to the second category, which is designated "quality assurance administrative procedures."

Each participant (i.e., government agency, public institution, or civilian contractor) in the project is responsible for quality assurance administrative procedures necessary to complement its approved quality assurance plan (quality assurance program description).

The BWIP technical work is prescribed by, and performed in accordance with, detailed procedures (e.g., laboratory procedures, special process procedures, test procedures, etc.). Each participant contractor is responsible for assuring that such procedures are prepared, reviewed, issued, controlled, and modified in accordance with approved procedures. Controls required by the quality assurance program are incorporated in these procedures. Technical procedures require review by the participant contractors' quality assurance personnel prior to use to verify that the necessary control features have been included.

Written instructions ordinarily consist of detailed sequences of steps, descriptive material specifying how an activity is to be performed, statements of actions necessary to carry out a nonconformance disposition, and inspection checklists, as an example.

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8.6.2.6 Criterion 6.0, Document Control

All BWIP project participants are required to maintain systems for the control of documents that direct or affect work within the scope of the project quality assurance program. These document control systems are required to adhere to the DOE-RL project management directive to establish a uniform document control system and are to provide for the following:

- Identification of documents to be controlled.
- Identification of responsibility assignments to prepare, review, approve, and issue documents.
- Review of documents and document changes for adequacy, completeness, and correctness prior to approval and issuance.
- Coordination and control of interface documents.
- Availability of correct and applicable documents at the work place.
- Assurance that proper documents are being used and that obsolete or superseded documents are not available for inadvertent use.
- Establishment and maintenance of up-to-date distribution lists.
- Establishment of an effective way for document users to determine whether a document is current and in effect.
- Explicit identification and control of documents released prior to required verification (e.g., technical review) and of any project data resulting from the use of such unverified documents prior to their verification.

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8.6.2.6.1 The U.S. Department of Energy-Richland Operations Office, Office of Commercial Nuclear Waste quality assurance documents

The BWIP Quality Assurance Plan (DOE-RL, 1987b), Basalt Quality Assurance Requirements Document (DOE-RL, 1987a), and implementing DOE-RL Office of Commercial Nuclear Waste quality assurance administrative procedures require review and approval by the Office of Geologic Repositories.

8.6.2.6.2 Integrating contractor, construction manager, and architect-engineer documents

Quality assurance plans and quality assurance administrative procedures prepared by the integrating contractor, construction manager, and architect-engineer require DOE-RL Office of Commercial Nuclear Waste approval.

8.6.2.6.3 Other participant contractor documents

Other participant contractors are required to submit their quality assurance plans and implementing quality assurance administrative procedures to the next higher participant in the project hierarchy for review and approval. However, the DOE-RL Office of Commercial Nuclear Waste will review quality assurance plans, quality assurance administrative procedures, and any substantive changes thereto for other government agencies performing BWIP work under memoranda of understanding with the DOE and for public institutions performing BWIP work on direct contract with the DOE.

8.6.2.6.4 Technical documents

Technical documents prepared by BWIP participant contractors as a basis for, or as part of, the BWIP site characterization, waste form, waste package design, or repository design, require DOE-RL Office of Commercial Nuclear Waste review and approval (the Project Management Plan (DOE-RL, 1986b) and the System Engineering Management Plan (DOE-RL, 1986a)).

Document review shall be accomplished by competent, independent reviewers on an individual review basis or in formal document review meetings. In either process, reviewer comments and the resolutions of comments are required to be documented for the record. Document approval requires determination by the approver(s) that all comments have been resolved satisfactorily.

8.6.2.7 Criterion 7.0, Control of Purchased Items and Services

The DOE-RL and BWIP participant contractors are required to institute measures to ensure that purchased items and services conform to the requirements specified in applicable procurement documents. Controls include evaluation and selection of suppliers with a demonstrated capability of providing the required items or services, verification that applicable controls are exercised during item processing or performance of the contracted services, and verification that completed items or services conform to procurement acceptance criteria. The responsible quality assurance organization is required to ensure that these controls are adequate and appropriate to the procurement. For precautions during procurement of instrumentation or equipment that is to be used for data collection during site characterization (where failure or malfunction would not be readily detectable either during data collection or evaluation), see Criterion 11.0, Section 8.6.2.11.

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8.6.2.7.1 Supplier quality assurance programs

The DOE-RL and BWIP participant contractors are required to determine, with the help or leadership of the responsible quality assurance organization, which elements of the BWIP quality assurance program are necessary to ensure that purchased materials, items, or services will meet technical needs and that they are supported by credible documentation. Suppliers may be required to implement quality assurance programs embodying those control elements, or the participant responsible for the procurement may elect to provide the quality assurance or procure it separately. Suppliers may be required to prepare formal quality assurance program descriptions for approval by the purchaser, or the purchaser may provide a questionnaire covering the required controls so that an acceptable, certified response to the questionnaire will constitute the necessary program description.

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8.6.2.7.2 Supplier selection and evaluation

Some of the research and analysis required for site characterization requires the services of specialists or of institutions or agencies whose work does not ordinarily involve formal quality assurance activities. In these instances, selection is based on technical capability, and establishment of quality assurance measures appropriate to the services to be performed is required at the outset of their work.

Except where technical requirements dictate selection on the basis of unique capabilities, procurement of BWIP project items or services within the scope of the BWIP quality assurance program will be made from suppliers who are preapproved.

Continued or repeat procurement from active suppliers or suppliers who have previously been used for BWIP work will be based, in part, on an evaluation of performance of that work.

8.6.2.7.3 Verification

The extent and nature of verification activities to be accomplished for procured items or services within the scope of the BWIP quality assurance program will be planned at the commencement of procurement activities. Such verification includes mandatory hold points for inspection or witnessing, where appropriate, and surveillance and (or) audit. In-progress inspection, witnessing, and surveillance includes review of the status of required documentation.

Acceptance of completed items or services is accomplished as follows:

- For items and materials, either one or a combination of the following: receipt inspection; certificate of conformance; source inspection, surveillance, and (or) audit; and post-installation testing. (Audits and surveillances alone are not sufficient for acceptance of items and materials)

- For services, in-progress audit and surveillance, as appropriate, and review/approval of the completed survey(s) (including technical reports, and completed studies, for example).

The responsible DOE-RL or participant contractor's quality assurance organization will verify that required documentation is received and that it complies with procurement requirements. Acceptability of the results of technical services (e.g., studies, analyses) will be determined by the organization initiating the procurement.

Where certificates of conformance are accepted, the responsible quality assurance organization verifies (by audit, surveillance, and (or) inspections) that the supplier's system for substantiating such certification is valid as implemented.

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8.6.2.7.4 Supplier-furnished documentation

Within the scope of the BWIP quality assurance program, the BWIP participant contractors are required to include provisions in procurement documents for the following supplier-furnished documentation:

- Documentation identifying the purchased service and the specific procurement requirements met (e.g., codes, standards, and specifications).

- Documentation identifying any procurement requirements that have not been met.

- Documentation describing any nonconformances from the procurement requirements that have been dispositioned "accept as is" or "repair."

Participant procedures for receipt of purchased items or services shall include explicit provisions for verifying that such documentation is delivered and acceptable.

8.6.2.7.5 U.S. Department of Energy-Richland Operations Office control of purchased items and services

The DOE-RL occupies the role of owner on the BWIP. The BWIP work is accomplished in the following ways:

- Through contracts between the DOE-RL and major contractors.
- Through interdepartmental agreements between the DOE and other Federal agencies.
- Through various contractual arrangements with non-Federal public agencies and institutions.
- Through subcontracts issued by major contractors.

The DOE-RL is responsible for administering procurement for BWIP, specifying the necessary quality assurance program, and ensuring that delivered items, materials, and services comply with applicable quality assurance requirements. Compliance with applicable provisions of the quality assurance program described in the DOE-RL Quality Assurance Plan is a condition of all BWIP procurement contracts.

8.6.2.8 Criterion 8.0, Identification and Control of Items, Materials, and Samples

Items, materials, and samples (for the purposes of this criterion hereinafter referred to as items) are identified and controlled at the BWIP in order to ensure (1) that the history of items is fully known from the time of receipt to the point of use (including traceability to nonconformances) and (2) that items are traceable from the sampling point to the point of consumption or long-term storage. (Note: continued traceability of items in storage is a part of records management.)

Each BWIP participant is responsible for identification and control of items in their custody. The integrating contractor provides overall project direction for identification and control systems. Each participant's procedures for identification and control of items shall provide traceability from the items to applicable documentation such as drawings, specifications, purchase orders, drilling logs, photographs (where used), test records, inspection documents, and nonconformance reports as applicable. These procedures also provide for verification and documentation of correct item identification prior to the release of items for use or analysis. They preclude assignment of a single identifier to multiple discrete items. In situations involving the subdivision of an item, identification of the individual items resulting from the subdivision shall be readily traceable to the original item.

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8.6.2.9 Criterion 9.0, Control of Special Processes

A special process is one in which the outcome cannot be characterized fully by nondestructive methods (i.e., where not all characteristics of the finished item can be evaluated by direct inspection or where direct inspection is disadvantageous).

Special processes used at the BWIP are explicitly identified in appropriate quality assurance program documents (quality assurance plan or quality assurance-related administrative procedures), and each participant contractor will develop and maintain a list of those processes that are to be controlled as special processes. The procedures that specify how individual special processes are to be performed are qualified by demonstrating that, when performed as specified, the process yields required results. In addition, these procedures shall establish the means and criteria for recording the acceptable accomplishment of the special process. Special process personnel are qualified by training (where appropriate) and demonstrating that they can perform the process(es) with the desired results. Where equipment affects the outcome of a special process, the equipment is similarly qualified. The responsible participant's quality assurance plan will describe the role the quality assurance organization plays in qualification of special process procedures, personnel, and equipment.

Where validity of site characterization depends on precise control of processes, procedures will include provisions for in-process documentation of process and parameters in such a manner as to enable after-the-fact reconstruction of affected work. In particular, records of process, personnel, and equipment qualification will be maintained as a part of the project records.

Site characterization may involve laboratory processes (e.g., chemical analyses) for which standard techniques have been developed within the scientific community and whose reliability has been demonstrated by broad usage. Such processes are not expected to require formal qualification within the BWIP. Independent verification that special processes are performed in accordance with the specified process procedure will be planned and accomplished on the basis of approved guidelines developed by the responsible participant contractor.

8.6.2.10 Criterion 10.0, Inspection

The following categories of inspection activities will be conducted as applicable during BWIP site characterization:

- Source inspection during designated procurements.
- Receipt inspection for procured items and materials.

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- In-process and acceptance inspections during and after fabrication, construction, installation, test, or modification work performed by BWIP participants.

- Inspection of samples.

Acceptance of the results of technical studies, design activities, etc., is not an inspection activity as discussed here.

Formal inspection is performed either by inspectors reporting to a participant's quality assurance organization or, where appropriate, by personnel possessing particular expertise who are independent of the item or activity being inspected. Quality assurance personnel performing inspection functions will be qualified in accordance with ANSI/ASME NQA-1-1986, Appendix 2A-1 (ANSI/ASME, 1986). Where inspection requires special expertise, the expert(s) will be selected on the basis of the required expertise, without regard to formal inspector qualification. In these cases, the participant's quality assurance inspection function will ensure that the specialist is properly oriented in the use of the necessary inspection equipment, forms, accept/reject practices, and reporting method.

It is required that the integrating contractor develop BWIP-wide standardization of certain inspection practices and formats to facilitate processing and later use of results. The integrating contractor also is responsible for ensuring the effectiveness of BWIP inspection activities. The DOE Basalt Quality Systems Division verifies that BWIP inspection activities are achieving intended results through audit and surveillance.

The BWIP inspection is performed in accordance with procedures, checklists, or explicit inspection steps in the work procedures. Regardless of the method of inspection, such instructions are reviewed and approved by quality assurance personnel prior to use.

Inspection instructions will provide, as necessary, for mandatory hold points or witness points beyond which work cannot proceed until the required inspection or witnessing has been accomplished. In addition, inspection instructions shall provide for the following:

- Identification of the characteristics and (or) activities to be inspected.

- A description of the method(s) of inspection to be used.

- Identification of the individual(s) or group(s) responsible for performing the inspection.

- Identification of required prerequisites (including required procedures, drawings, specifications, and revisions) and working conditions for the work to be inspected.

- A means for recording inspector or data recorder identity and the results of the inspection operation.

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- Specification of measuring and test equipment required to perform the inspection, as well as accuracy requirements.
- Acceptance and rejection criteria, or reference to the requirements documents (e.g., drawings) that specify these criteria.
- When applicable, criteria for determining when inspections are required.

Records are generated for all inspection activities that substantiate quality. These records shall address, as a minimum, the following:

- Item or activity inspected.
- Date of inspection.
- Location of inspection.
- Identification of inspector.
- Type of inspection (including reference to controlling procedure, drawing, or specification and revision thereof).
- Unique identification of tools or equipment used, if applicable.
- Results and acceptability.
- Reference to action taken in connection with nonconformances.
- Information concerning the resolution of conditions adverse to quality.

These records are controlled, maintained, and stored in accordance with the requirements described in Section 8.6.2.17.

Participant contractors whose activities include work requiring inspection will establish and implement procedural requirements for documentation of inspection results and documented evaluation of the acceptability of results. Verification that activities have been accomplished in accordance with, and that results conform to, established requirements is documented as performed and is retained as part of the formal BWIP record.

8.6.2.11 Criterion 11.0, Test Control

In addition to testing accomplished on traditional construction projects, BWIP activities conducted for the purpose of acquiring data for site characterization (e.g., sample collection, sample analysis, tests of rock behavior or hydrologic dynamics, etc.) are considered site characterization test activities. Such data acquisition activities will be performed with controls

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applied to traditional testing such as procedures, controlled selection and use of measuring and test equipment, verification that specified prerequisites (when applicable) are met, etc. Where the course of action has to be determined as acquisition proceeds, based on ongoing results, it is expected that needs will be recognized during planning and provisions will be made for field decisions and (or) other appropriate actions. The intent is to ensure a controlled degree of necessary flexibility.

8.6.2.11.1 Test plans and procedures review

Testing requirements are derived basically from information needs specified in 10 CFR 60 (NRC, 1987a) and DOE site characterization guidelines in 10 CFR 960 (DOE, 1987) and the issues are identified in the geologic repository program Mission Plan (DOE, 1986b). The four major issues identified in the Mission Plan have been translated into more detailed issues directly applicable to characterization of the BWIP site. Information needs strategy is established in response to those site-specific issues and iterative results of performance assessment studies and conceptual design.

Test planning and test procedures are to be reviewed and approved in accordance with controls established in response to Criterion 3.0 (see Section 8.6.2.3). Planning for data acquisition and preparation of data acquisition procedures are primary links in the definition of inputs to subsequent design and, therefore, are in the earliest phase of the design process. The planning activity and procedure preparation, review, and approval are to be handled under the same controls as those applied to all other design phases.

8.6.2.11.2 Uncertainties and error

To the extent practicable, test planning is expected to include (1) identification of potential sources of error and (or) uncertainty and (2) analysis of the degree of uncertainty or error these sources could produce in the test results. Parameters that need to be measured and (or) controlled to minimize such uncertainties or errors and to assure adequate control of the test shall be addressed explicitly in test procedures.

8.6.2.11.3 Special considerations for some test equipment and instrumentation

For instrumentation or equipment used in data collection, the BWIP participant contractors shall consider whether failure or malfunction of the instrumentation during testing will be detectable, either during data collection or by examination of the data. Where ability to detect such failure or malfunction is questionable, (1) technical and quality procurement requirements will be selected specifically to minimize the likelihood of undetectable

anomalies and (2) test planning and procedures will include any special provisions for equipment/instrumentation configuration, installation, and use that can further reduce risk of undetectable failure or malfunction.

8.6.2.11.4 Personnel qualification

The BWIP participant contractors are required to establish appropriate descriptions of the qualifications required of personnel performing site characterization testing. These qualification descriptions may be stated in the form of the minimum qualifications required for personnel to fill specific positions. Participant contractor management shall assure that personnel assignments to testing duties are consistent with the individuals' qualifications or that explicit plans are in place and are implemented to bring the individuals' qualifications into conformance.

8.6.2.11.5 Test procedure content

Test procedures shall include the following elements:

- Requirements and acceptance limits, including precision and accuracy, contained in applicable documents.
- Test prerequisites such as calibrated instrumentation, presence of specified test equipment and instrumentation, completeness and (or) acceptability of the item or condition to be tested, specified environmental conditions, and provisions for data collection and storage. For tests of long duration, specific provisions will be made for instrumentation with calibration intervals shorter than expected test duration. Such provisions are to be designed to ensure validity of data throughout the test.
- Instructions for performing the test.
- Mandatory hold points or witness points (as required).
- Acceptance/rejection criteria, including required levels of precision and accuracy. (Note: "Accept/reject criteria" means that those features or characteristics of a procedure that make it possible to determine whether the work has been, or is being, performed in such a way that it produces the intended results. A data acquisition task produces output that, in itself, cannot be characterized as acceptable or unacceptable. However, the task of acquiring the data is acceptable if all specified prerequisites were met and the work was accomplished in the specified manner. In that instance, the accept/reject criteria are simply the conditions and methods stated in the procedure.)

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- Methods of data analysis (which may, however, appear in data analysis procedures other than the procedures used for performing the testing).

- Methods of documenting or recording test data and results.

- Provisions for assuring and documenting the fact that test prerequisites were met.

8.6.2.11.6 Test results evaluation and acceptance

The BWIP participant contractors shall assure that test results have been evaluated and their acceptability determined by the responsible individual or groups, as indicated in applicable subsections of Criterion 3.0 (see Section 8.6.2.3). Test records shall include the following information where applicable:

- A description of the type of test or observation.
- The date and results of the test.
- Information related to conditions adverse to quality.
- Data recorder identity.
- Evidence as to acceptability of results.
- Action taken to resolve any discrepancies noted.

The DOE-RL Office of Commercial Nuclear Waste will verify by surveillance and audit that the integrating contractor's direction and management is producing effective test controls throughout the BWIP.

8.6.2.12 Criterion 12.0, Control of Measuring and Test Equipment

The integrating contractor is responsible for ensuring that adequate calibration control systems are implemented for measuring and test equipment to be used at the BWIP. These systems shall provide for the following:

- Use of calibration standards traceable to nationally recognized standards.

- Selection of measuring and test equipment on the basis of application requirements.

- Tagging or other appropriate and effective means of knowing calibration status of individual items of measuring and test equipment.

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- Specified calibration intervals based on accuracy, purpose, degree of usage and stability characteristics, and other conditions that could affect measurement.
- Recalibration based on measuring and test equipment found to be damaged or consistently outside allowable calibration limits.
- Reevaluation of results obtained by use of measuring and test equipment subsequently determined to be out of calibration.
- Traceability of equipment to calibration test data.
- Evaluation and acceptance of calibration results by authorized personnel.

When a nationally recognized standard does not exist, the basis for calibration is documented and reviewed. Where beyond the state-of-the-art or untried methods are being employed for calibration, an evaluation shall be made by the organization that established the calibration requirements to determine if a peer review of the proposed method is required.

The responsible line management organizations within the BWIP shall ensure that the calibration controls established and implemented by their parent organizations are adequate and effective. Quality assurance involvement includes review of, and concurrence with, calibration program procedures, as well as audit and surveillance of calibration activities.

The DOE Basalt Quality Systems Division verifies effectiveness of the integrating contractor's management of the calibration control system by surveillance and audit.

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8.6.2.13 Criterion 13.0, Handling, Storage, and Shipping of Items, Materials, and Samples

Each BWIP participant contractor having tasks that include receipt, processing, or storage of items, materials, or samples within the scope of the BWIP quality assurance program is required to establish and implement controls that minimize the risk of loss, damage, or deterioration. These procedures are to require that specific handling, storage, preservation, packaging, and shipping instructions be prepared by knowledgeable, responsible individuals and that such activities be performed in accordance with approved instructions by suitably trained personnel. Where appropriate, qualifications of special lifting equipment, slings, and hoists will be addressed in detail.

The integrating contractor is responsible for ensuring BWIP-wide controls for handling, storing, and shipping of items, and the DOE Basalt Quality Systems Division verifies effectiveness of these controls by surveillance and audit.

8.6.2.14 Criterion 14.0, Inspection, Test, and Operating Status

Controls for maintaining and indicating the status of the BWIP inspections, tests, and operations shall be established and implemented for the following purposes:

- Ensuring that required inspections or tests, or required inspection or test steps, are not inadvertently bypassed.
- Ensuring that personnel working on, or in the vicinity of, site characterization test or operating equipment are aware of the operating status of the equipment.

The BWIP participant contractors are required to establish and implement procedures that provide for use of status indicators (e.g., tags, markings, area postings, etc., as appropriate) to show inspection, test, or operating status. In addition, logs, status boards, or other suitable controls are required where knowledge of status is required at locations remote from the actual inspection, test, or operation activity.

8.6.2.15 Criterion 15.0, Control of Nonconforming Items or Samples

Each BWIP participant contractor is required to identify any nonconforming item, material, or sample by marking, tagging, or segregating it immediately on detection of the nonconformance. Such identification will provide clear indication of the nonconforming condition of the item, material, or sample to anyone who might otherwise process or use it.

Any nonconformance is required to be documented upon discovery and reported promptly for evaluation and disposition. The BWIP participant contractors shall establish and implement systems for tracking nonconforming items until disposition has been accomplished and for preventing inadvertent use of such items.

Each participant contractor's procedures for control of nonconformances shall provide for authorized, knowledgeable individuals to evaluate the significance and project implications of the nonconformance; determine what disposition is to be made of the nonconforming item, material, or sample; provide appropriate instructions for carrying out the specified disposition; and specify accept/reject criteria (where applicable) for verifying that the specified disposition has been accomplished correctly. Personnel responsible for the quality assurance function for the participant contractor will participate in the evaluation and disposition process for nonconformances.

Decisions to use the nonconforming items, materials, or samples as is (i.e., use-as-is) or to restore them to usable condition without returning them to a fully conforming condition (i.e., repair) require technical review and approval at the next higher level of BWIP participation (e.g., disposition

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decisions of "use-as-is" or "repair" made by the integrating contractor require DOE-RL Office of Commercial Nuclear Waste review and approval). Technical justification for the acceptability of a nonconforming item dispositioned repair or use-as-is shall be documented. Nonconformances to design requirements dispositioned use-as-is or repair shall be subject to design control measures commensurate with those applied to the original design.

Each participant contractor's procedures for control of nonconforming items, materials, or samples shall contain provisions for documented verification that disposition of such items, materials, or samples is carried out in accordance with instructions and meets the specified accept/reject criteria.

Prior to initiation of site characterization activities, the BWIP will establish a system for monitoring and analyzing nonconformance trends on a BWIP-wide basis and for initiating appropriate action where the need is indicated.

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8.6.2.16 Criterion 16.0, Corrective Action

Corrective action at the BWIP consists of (1) action to correct observed conditions that do not conform to specified requirements and (2) action to prevent recurrence of problems. Problems are defined as conditions that could have an adverse effect on items important to safety or important to waste isolation, that could adversely affect the credibility of site characterization conclusions, that could endanger BWIP personnel or property, or that could have a major impact on BWIP costs or schedules.

The integrating contractor is responsible for establishing and ensuring implementation of a BWIP-wide program for formal corrective action to prevent recurrence of significant problems. The program shall provide for the following:

- Evaluation of participant contractor reported problems to determine significance, including potential implications to previously completed BWIP work.
- Investigation to determine the root cause of problems determined to be significant.
- Action to eliminate or compensate for the identified root cause.
- Quality assurance verification that the defined preventive action is implemented as planned.

8.6.2.17 Criterion 17.0, Quality Records

The integrating contractor is responsible for establishing and operating the BWIP records management system in accordance with the DOE-RL direction for the records program. The system is described in the BWIP Records Management Plan (Rockwell, 1987), which provides direction to all BWIP personnel regarding collection, administration, storage, and retrieval of BWIP records/documents and one-of-a-kind items after their preparation for the BWIP.

It is important to distinguish between a document (which is any written or pictorial information describing, defining, specifying, reporting, or certifying activities, requirements, procedures, or results) and a record (which furnishes documentary evidence of the quality of items and of activities affecting quality; e.g., boring logs, maps, geologic survey notes, geophysical data, results of peer reviews, laboratory data, and data reduction and interpretation).

A document is considered to be a quality assurance record when the document has been completed. Documents, records, and items (e.g., core samples) that are to become part of the formal record are transmitted to the integrating contractor for the necessary processing and storage. Organizational responsibilities for the records management system are specified in appropriate procedures.

Geotechnical samples will not be stored in accordance with the requirements for storage of quality assurance records listed in NQA-1-1986 (ANSI/ASME, 1986). Samples will be afforded archival controls and protection in a building for the period during which additional examination or analysis by DOE or the NRC may be needed. No provision in the storage system will prevent or mitigate the natural time-dependent deterioration processes inherent to the sample materials that will destroy or substantially change sample properties, so they may not lend credibility to previous test results or analysis.

The BWIP records in long-term storage shall be kept in a facility that meets applicable requirements listed in NQA-1-1986 (ANSI/ASME, 1986) for protecting records from deterioration and disaster.

8.6.2.18 Criterion 18.0, Audit and Surveillance

The DOE-RL Office of Commercial Nuclear Waste and each BWIP participant contractor are required to establish and maintain formal internal quality assurance audit programs that comply with requirements stated in the BQARD (DOE-RL, 1987a) and in the BWIP Quality Assurance Plan (DOE-RL, 1987b). Participant contractors who award subcontracts for BWIP work (thus establishing subtier participant contractors) are required to conduct external audits of the quality assurance programs of the subtier participants for whom they

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are responsible. The integrating contractor, in its project management role, also is required to schedule and conduct audits of all other major contractors, including the construction manager and the architect-engineer.

The Basalt Quality Systems Division audits the BWIP activities indicated below:

- Activities within the scope of this quality assurance program performed by the other organizations within the DOE-RL Office of Commercial Nuclear Waste.
- Implementation of the BWIP quality assurance program as established and managed by the integrating contractor.
- Selected activities throughout the BWIP, with emphasis on performance of major contractors in their implementation of the BWIP quality assurance program as it applies to them and on the effectiveness of contractor audit programs.

In addition, Basalt Quality Systems Division auditors accompany audit teams of the integrating contractor and other BWIP participant contractors on selected audits to observe audit performance and to evaluate the effectiveness of contractor audit processes. The DOE-RL Office of Commercial Nuclear Waste is audited by the Office of Geologic Repositories and the Environment, Safety, Health and Quality Assurance Division at regular intervals.

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8.6.2.18.1 Audit program content

Quality assurance audits within the BWIP address the following questions:

- Is the audited participant carrying out its approved quality assurance program?
- Are the controls and (or) control systems defined in the audited participant's quality assurance program working effectively?
- Does the record provide convincing objective evidence that the controls and (or) control systems have been, and are being, rigorously applied (i.e., is a rigorous record being compiled)?
- Does the audited participant contractor exhibit an acceptable degree of procedural discipline?

8.6.2.18.2 Audit scheduling

The Basalt Quality Systems Division and every BWIP participant contractor who is required to conduct a quality assurance audit program shall develop, maintain, and implement an approved audit schedule and shall update the schedule periodically.

Audit schedules shall be based on the quality level of planned and ongoing BWIP work. Schedules shall provide for (1) verification, early in the life of a discrete task or work phase, that approved controls are in place and are being applied and (2) verification at appropriate later points in the life of the task or work phase that comprehensive, credible evidence exists to demonstrate control effectiveness.

The audit scheduling process shall consider surveillance results as an important factor. That is, surveillance and audit shall be regarded as complementary methods of assessing quality assurance program effectiveness and credibility. Although formal updates to audit schedules are required to be issued at regular intervals, surveillance results shall be evaluated on a continuing basis for indications that (1) scheduled audits should be rescheduled or should have their scope or direction changed or (2) additional audits should be scheduled.

Special audits will be scheduled in the event of (1) major changes to a participant's quality assurance program or organization or (2) discovery of major areas of concern. Participant contractors shall submit audit schedules and schedule changes that occur between regular issues of updated schedules to the next higher participant in the BWIP hierarchy. Change submittals shall include the rationale for the reported change(s).

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8.6.2.18.3 Auditor qualification

The use of a certified lead auditor as team leader for every quality assurance audit is a formal BWIP requirement. Lead auditor qualification complies with the requirements of NQA-1-1986 (ANSI/ASME, 1986).

The team leader shall participate in the selection of auditors to staff the team and shall be responsible for assuring that all team members are competent to perform their assigned portions of the audit by virtue of prior experience and (or) specific, documented orientation or training during the audit preparation phase. In addition, the team leader shall ascertain that members of the audit team are independent with respect to activities they will audit (i.e., that no audit team member audits an activity for which that individual was directly responsible or provided direction or guidance).

8.6.2.18.4 Audit preparation

As a minimum, preparation for individual audits shall include study of auditee procedures applicable to the activities to be audited, evaluation of relevant surveillance results, review of relevant corrective action, evaluation of the results of previous audits of the same activities, review of trend data, and review of the current status of the work.

8.6.2.18.5 Audit performance

Audits shall be performed to checklists or procedures prepared or identified during audit preparation. Conditions observed during performance of a part of the audit may open additional areas of interest or may warrant a change of emphasis. However, if such conditions are outside the scope of the audit, the auditor shall bring them to the attention of the audit team leader, who will refer them to the proper individual or organization for investigation or other appropriate action. Such out-of-scope conditions shall not interfere with proper accomplishment of the objectives of the audit in work.

Audit performance will include adequate documentation of the evidence examined and conditions observed so that a sound basis exists for conclusions drawn and reported.

8.6.2.18.6 Audit reports

Audit results shall be reported to the audited entity, upper management of the audited organization(s), and upper management of the auditing organization. Copies of audit reports will be forwarded to higher level organizations in accordance with distribution instructions issued by the DOE-RL Office of Commercial Nuclear Waste for BWIP compliance. These distribution requirements will reflect any DOE-HQ direction.

Audit reports will explicitly recognize those quality assurance program elements within their scope that are being implemented effectively, as well as identifying deficiencies in implementation.

8.6.2.18.7 Exemptions from internal audit requirements

Some research and development organizations have no prior experience with internal quality assurance audits, and it would not be an effective application of project resources to insist on development of the audit capability. In such instances, the responsible participant contractor at the next higher level in the BWIP hierarchy may elect to perform the necessary audits or may require that a third party be engaged to perform the audits.

Typical situations justifying this approach include the following:

- Academic institutions.
- Government agencies participating under memoranda of understanding.
- Small, specialized organizations or individual contributors (such that no uninvolved staff is available for auditing).

8.6.2.18.8 Surveillance

The DOE-RL Office of Commercial Nuclear Waste and each BWIP participant contractor required to conduct a quality assurance audit program also will develop and implement an approved surveillance plan that will be updated and reissued at periodic intervals.

Surveillance is the documented observation and (or) examination of work that is in progress, and surveillance results constitute a part of the formal BWIP record. Surveillance may include any combination of the following:

- Actual observation of the physical performance of work.
- Observation of the work place for the presence of suitable conditions and adequate housekeeping and safety measures.
- Observation of related access control, fire prevention provisions, etc.
- Review or spot checks of documents in preparation.
- Review or spot checks of procedures or instructions governing the work.
- Evaluation or verification of the presence and effectiveness of applicable controls.
- Discussion with personnel performing or supervising the work.

8.6.2.18.9 Qualification for surveillance

Surveillance of the BWIP shall be performed by personnel who are knowledgeable in the kind of work they are observing. Certification of surveillance personnel qualifications is not required, but the discipline or specialty of the individual performing surveillance is expected to bear a clear relationship to the field under surveillance. Quality assurance personnel performing surveillance of controls applied to technical activities are not required to be qualified in the technical discipline(s) involved.

8.6.2.18.10 U.S. Department of Energy-Richland Operations Office Assistant Manager of Commerce Nuclear Waste surveillance

Surveillance performed by Basalt Quality Systems Division personnel shall be controlled by DOE-RL Office of Commercial Nuclear Waste procedure. Technical personnel perform surveillance of work within their areas of expertise and

evaluate technical effectiveness of applicable controls. The Basalt Quality Systems Division personnel perform surveillance of ongoing control activities.

8.6.2.18.11 Surveillance by participant contractors

The BWIP participant contractors are required to provide appropriate levels of surveillance over activities for which they are responsible. Surveillance activities shall address both technical and control adequacy of work in progress and shall be performed and documented in accordance with approved procedures.

8.6.2.18.12 Audit and surveillance follow-on activities

Each participant contractor shall address deficiencies identified by audit or surveillance with prompt, vigorous corrective action. Adverse findings identified as significant shall be investigated to determine the root cause of the deficiency and to define the action that will prevent recurrence. The auditing or surveilling organization shall perform the following:

- Evaluate responses to significant deficiencies identified during audit or surveillance for evidence that the reported cause appears capable of having produced the observed condition(s) and that the proposed course of corrective action addresses the alleged cause in such a way as to have a high likelihood of long-term prevention of recurrence.
- Confirm timely implementation of approved corrective action(s).
- Verify that the corrective action was effective in preventing recurrence.

The BWIP participant contractors shall maintain tracking and trending systems that will provide long-term visibility of significant problems so that any recurrence will be recognized immediately.

8.6.3 ORGANIZATION OF THE BASALT WASTE ISOLATION PROJECT WITH RESPECT TO QUALITY ASSURANCE

The responsibility for the BWIP is defined for the several participating organizations. Specific rules and responsibilities for each level of the administrative hierarchy (see Fig. 8.6-3) are as described in the following subsections.

8.6.3.1 Office of Civilian Radioactive Waste Management

The Office of the Director, DOE-HQ Office of Civilian Radioactive Waste Management, is charged with the implementation of the Nuclear Waste Policy Act of 1982 (NWPA, 1983). The specific functions of the director's office are to provide overall policy recommendations to the Office of the Secretary of Energy; to ensure that the overall direction and pace of the program proceed as mandated by the Nuclear Waste Policy Act of 1982 (NWPA, 1983); to provide policy guidance, direction, and control to the associate directors; and to provide policy guidance to the project offices in implementing major decisions beyond the scope of the day-to-day authority of the associate directors (Fig. 8.6-5). The director of the Office of Civilian Radioactive Waste Management has ultimate responsibility for establishing and maintaining an effective program-wide quality assurance program. The Director of the Office of Civilian Radioactive Waste Management assigns management functions, responsibilities, and authorities to the director for Policy and Outreach and to three associate directors for Resource Management, Geologic Repositories, and Storage and Transportation Systems.

Within Policy and Outreach of Civilian Radioactive Waste Management, the quality assurance manager has the lead responsibility for quality assurance management policy overview and coordination for the overall program. Within the Office of Civilian Radioactive Waste Management, the quality assurance manager has direct access to the director to report on the status and adequacy of quality assurance policies, plans, and activities for the overall program and to recommend or cause resolution of general quality assurance management policy issues.

8.6.3.2 Office of Geologic Repositories

Within the Office of Civilian Radioactive Waste Management, the associate director of the Office of Geologic Repositories is responsible for the screening and selection of sites; the design, licensing, construction, and operation of repositories; the management of research and development for repositories; the implementation and management of specific quality assurance requirements, plans, and policies and approval of site quality assurance plans, and quality assurance administrative procedures (see Fig. 8.6-5). Technical, programmatic, and quality assurance direction originate from this office to the respective repository project offices. Additional details regarding the responsibilities of this office are contained in the Quality Assurance Plan for High-Level Radioactive Waste Repositories (DOE, 1986d).

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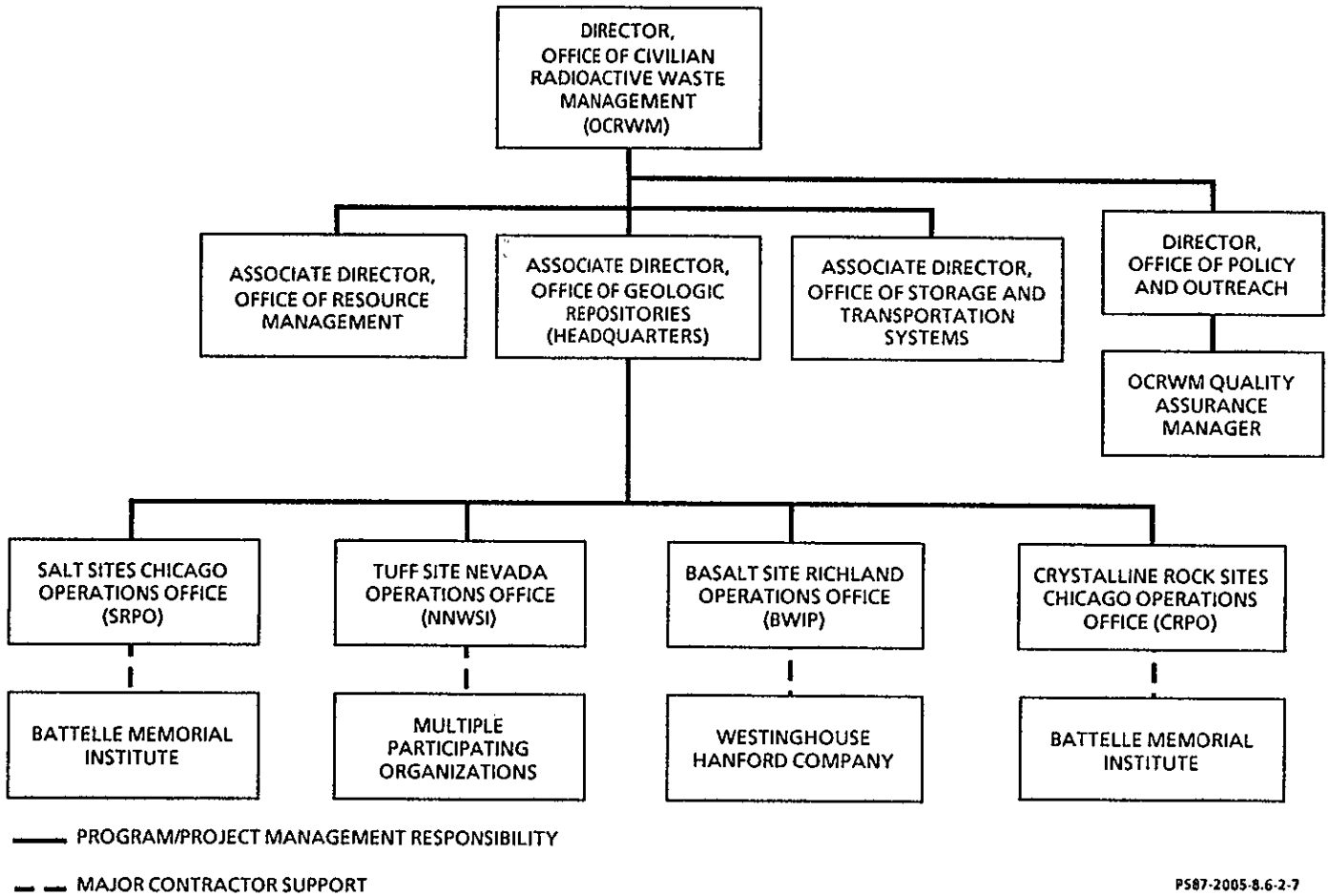

Figure 8.6-5. Office of Civilian Radioactive Waste Management.

CONSULTATION DRAFT

8.6.3.3 U.S. Department of Energy-Richland Operations Office

The manager, DOE-RL, has the ultimate responsibility and authority for maintaining an effective program of quality assurance for the BWIP in compliance with mandated requirements. Delegations to DOE-RL organizations associated with the implementation of quality assurance are depicted in Figure 8.6-3.

The manager, DOE-RL, has assigned the assistant manager, Office of Commercial Nuclear Waste to the role of BWIP Project Manager, the authority to implement and direct the BWIP. The BWIP Project Manager is responsible for providing overall DOE management of the BWIP in compliance with the BWIP quality assurance plan through all phases of the BWIP, including siting, site characterization, design, construction, operation, and institutional interfacing. The BWIP Project Manager has established two divisions to provide day-to-day management of the BWIP, the Basalt Waste Isolation Division, and the Basalt Quality Systems Division.

In quality-assurance-related matters, the BWIP Project Manager is responsible for the following:

- Approving the BWIP quality assurance plan and the procedures necessary for its implementation.
- Approving project plans, as necessary, to permit the Basalt Waste Isolation Divisions to fulfill their technical and quality assurance program requirements.
- Ensuring adequate funding for quality assurance activities.
- Effectively implementing the quality assurance program.
- Approving formal quality and technical program direction issued by the Basalt Waste Isolation Division and Basalt Quality Systems Division to BWIP participant contractors.
- Ensuring and evaluating the effectiveness of implementation of the quality assurance program.
- Evaluating the quality of delegated work as reported by the Basalt Waste Isolation and Basalt Quality Systems Divisions.
- Evaluating management assessment reports of quality assurance program implementation.
- Fulfilling other management responsibilities as assigned by the DOE-RL.

The assistant manager, Office of Commercial Nuclear Waste, chairs the DOE-RL Readiness Review Board, which determines whether all prerequisites for a given item of selected work are in place and satisfactory, prior to the commencement of that activity.

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The director, Basalt Quality Systems Division, reports on quality assurance program status to the Assessment Review Committee and coordinates implementation of recommendations and (or) required program changes. The BWIP Project Manager convenes an Assessment Review Committee meeting at least annually to assess the scope, adequacy, status, and effectiveness of the BWIP quality assurance program. The BWIP Project Manager selects not less than two committee members from the DOE-RL director level or above outside the Quality Systems Division, and (or) executive level management of consultant or other organizations, as appropriate.

The director, Procurement Division, reports to the manager, DOE-RL, through the assistant manager, Office of Assistant Manager for Administration. The director, Procurement Division, is responsible for establishing and implementing a procurement process and executing contracts that are consistent with BWIP quality assurance requirements. These responsibilities include reviewing procurement documents in accordance with approved procedures (e.g., statements of work, procurement requests, and preprocurement plans) and administering the process that results in approved contracts and subcontracts.

The Basalt Quality Systems and Basalt Waste Isolation Divisions participate in evaluation boards, and they review and concur in final contract and subcontract packages prior to award.

In addition, the Procurement Division provides review and approval of DOE-RL procedures that affect procurement activities. The director of the Procurement Division fulfills other responsibilities as assigned in the BWIP Quality Assurance Plan (DOE-RL, 1987b).

The director, Basalt Waste Isolation Division, reports to the BWIP Project Manager and is responsible for the following:

- Effectively implementing the quality assurance plan in the engineering, geoscience, and licensing areas.
- Evaluating the technical effectiveness of quality assurance program control by participants prior to and during ongoing work.
- Serving on and providing support for the DOE-RL Readiness Review Board.
- Preparing and issuing management plans and instructions as required.

The director, Basalt Quality Systems Division, reports to the BWIP Project Manager and exercises the highest direct-line authority in BWIP for quality. This director has no other responsibilities that prevent the devotion of full attention to quality activities. The director's responsibilities include the following:

- Preparing and maintaining the BWIP Quality Assurance Plan (DOE-RL, 1987b) and procedures necessary for its implementation.

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- Establishing requirements for BWIP participant contractors' quality assurance programs.
- Reviewing and approving the quality assurance plan and implementing quality assurance administrative procedures prepared by the integrating contractor.
- Evaluating the integrating contractor's recommendations for approval of the quality assurance program descriptions and quality assurance administrative procedures prepared by the construction management contractor and architect-engineer.
- Approving the quality assurance program and administrative procedures of the construction management contractor and the architect-engineer for use on the BWIP.
- Exercising BWIP overview of overall quality assurance program implementation.
- Verifying effective implementation of the BWIP Quality Assurance Plan by the Basalt Waste Isolation Division.
- Reviewing and (or) specifying quality assurance requirements in procurement documents.
- Approving contractor and subcontractor quality assurance programs when their work is not subject to review by the integrating contractor.
- Approving government agency quality programs when the scope of work is covered by a memorandum of understanding.
- Providing direct quality assurance support to the Basalt Waste Isolation Division.
- Serving on, and providing support, for the DOE-RL Readiness Review Board.

To promote communication and to assure positive attention to quality issues within the DOE-RL and between the Basalt Waste Isolation and Basalt Quality Systems Divisions and the BWIP participant contractors, lines of communication are characterized as follows (see Fig. 8.6-3):

- Quality assurance direction and policy guidance from DOE-HQ reaches DOE-RL through the Office of Geologic Repositories, as specified in the Quality Assurance Plan for High-Level Radioactive Waste Repositories (DOE, 1986d), the requirements documents it cites, and directives issued from that office.

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The BWIP Quality Assurance Plan, and the quality assurance administrative procedures of the Basalt Waste Isolation and Basalt Quality Systems Divisions are submitted to the Office of Geologic Repositories for review and approval. Office of Geologic Repositories personnel verify effective implementation of the project quality assurance program and project compliance with applicable regulations, codes, and standards.

Free, informal flow of information between DOE-RL personnel engaged in BWIP quality assurance-related activities and responsible personnel in the Office of Geologic Repositories is encouraged to supplement formal reporting.

- Formal direction to BWIP participant contractors concerning quality assurance program direction is issued at the BWIP Project Manager or the Basalt Quality Systems Division director level within the DOE-RL. Typically, quality assurance guidance is issued by the Basalt Quality Systems Division. This guidance serves to establish a clear line of authority to the contractors for direction of their quality assurance program.

- Formal internal communications exist among all levels within the DOE-RL and between the DOE-RL and DOE-HQ. Typically, communications take the form of memoranda and planned reporting such as weekly and monthly status reports.

- The BWIP has established a quality concerns program by which individuals are encouraged to identify and report quality problems and to initiate, recommend, and provide solutions. Within the BWIP, such activities are documented and tracked and individuals notified of resolutions taken.

The lines of communication among the various BWIP project participants include the following: (1) the DOE-RL to integrating contractor; (2) integrating contractor to architect-engineer, construction manager, or other BWIP participating contractor; and (3) contractor to supplier. When one of the DOE's subsidiary agencies is working under a memorandum of understanding, communications are initiated by the DOE-RL.

Communication from the DOE-RL regarding quality-assurance-related activities within the DOE-RL organizations is promoted through the following:

- Periodic staff meetings.

- Quality assurance program progress and status reports outlining the status of quality assurance activities, problems and nonconformances, quality trends, readiness reviews, and results of audits and surveillances.

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At least once each quarter, the DOE-RL Basalt Quality Systems Division chairs a meeting of representatives from each quality assurance organization of the major BWIP participant contractors to receive reports and discuss matters relevant to quality assurance program implementation. The results of these meetings are documented.

Within the DOE-RL and between the DOE-RL and DOE-HQ, channels of communication and defined authorities exist to resolve disputes that shall arise from differences of opinion on quality-assurance-related issues. Should the principals in any dispute be unable to reach resolution, problems shall be elevated to successively higher levels of management within the field office (branch chiefs and team leaders, division directors and project managers, assistant managers, and ultimately the field office manager) and eventually to the DOE-HQ Office of Civilian Radioactive Waste Management.

An annual plan is prepared and issued by the DOE-RL Basalt Quality Systems Division identifying scheduled audits to be performed. The plan and any revisions are approved for issuance by the DOE-RL Office of Commercial Nuclear Waste. Revisions are issued to reflect changes in the status or importance of work in progress. In addition, unscheduled verification activities are performed by the DOE-RL Office of Commercial Nuclear Waste as the need is identified.

At times, the Basalt Waste Isolation Division and (or) Basalt Quality Systems Division engage the services of external peer review groups and individuals to provide independent, expert overview of BWIP activities to verify the appropriateness of program direction, test results, etc. These reviews are formally documented, and the Basalt Waste Isolation and Basalt Quality Systems Divisions review the qualifications of participants to ensure a level of education, training, and experience commensurate with planned activities.

In addition to daily informal communications between DOE-RL organizations and the BWIP participant contractors, there are formal organizational responsibilities to ensure effective implementation of the quality assurance program. The Basalt Waste Isolation Division and the Basalt Quality Systems Division, through their technical and quality assurance overview roles, provide the feedback necessary for overall contractor evaluation and the long-term and day-to-day management of work.

Organizations and persons performing quality-assurance-related activities (primarily the Basalt Waste Isolation Division, Basalt Quality Systems Division, and Procurement Division) have direct access, as provided through established surveillance and audit procedures and normal communication channels, to appropriate management levels to permit timely identification of quality-related problems, recommendation and initiation of corrective actions (including review of recommended corrective actions provided by others), and verification of corrective action implementation.

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8.6.3.4 BWIP participant contractors

Westinghouse Hanford Company (Westinghouse) is the DOE-RL operating contractor for BWIP site waste management, and Westinghouse BWIP has been assigned as integrating contractor for the BWIP. Westinghouse BWIP is responsible for assuring the coordination and implementation of quality assurance programs by all BWIP participant contractors. All BWIP participant contractors are responsible for documenting and implementing effective quality assurance programs in compliance with contractual requirements.

The integrating contractor has two roles in the BWIP: (1) project management under DOE-RL direction and (2) direct performance of specified technical work. In the project management role, the integrating contractor ensures that the activities of all BWIP participants are planned and carried out in such a manner as to provide coherent site characterization and design. In the direct performance role, the integrating contractor's technical resources are applied to designated conceptual design and development tasks and site characterization.

The integrating contractor's project management role includes responsibility for ensuring that DOE-RL Office of Commercial Nuclear Waste policy and direction is implemented effectively and consistently across the BWIP while the integrating contractor's quality assurance organization provides the following BWIP services:

- Reviews and recommends DOE-RL approval of quality assurance program descriptions and quality assurance administrative procedures prepared by the construction manager and the architect-engineer.

- Approves the quality assurance plans and quality assurance administrative procedures prepared by (1) BWIP participant contractors under direct contract to the DOE for their BWIP work (other than the architect-engineer and construction manager) and (2) all BWIP participants under direct contract to the integrating contractor for their BWIP work.

- Establishes BWIP-wide systems and (or) methods for implementing quality assurance program elements where such uniformity produces important cost and (or) control benefits.

- Verifies effective implementation of the quality assurance program by means of audit, surveillance, trending, and management assessment of quality assurance activities of the architect-engineer, construction manager, other BWIP participants under direct contract to the DOE for their BWIP work, and all BWIP participants under direct contract to the integrating contractor for their BWIP work.

- Ensures that applicable elements of its quality assurance program are effectively implemented for direct work performed in-house.

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Each of the other BWIP participant contractors is responsible for the following:

- Developing and implementing a quality assurance program that meets all applicable requirements identified in the BQARD (DOE-RL, 1987a), is consistent with the BWIP quality assurance program described in the BWIP Quality Assurance Plan (DOE-RL, 1987b), and reflects any BWIP-wide quality assurance systems or methods specified by the integrating contractor.

- Approving the quality assurance plans and quality assurance administrative procedures of subcontractors doing BWIP work under contract to them.

- Verifying effective implementation of their internal quality assurance program and the quality assurance programs of subcontractors doing BWIP work under direct contract to them.

Within DOE-RL Office of Commercial Nuclear Waste and each BWIP participant contractor organization, a management position has been identified that retains overall authority and responsibility for the quality assurance program. This position, occupied by an individual with appropriate management and quality assurance knowledge and experience has the following characteristics:

- Is at the same or higher organizational level as the highest line manager directly responsible for performing activities affecting quality (e.g., design, engineering, site investigations, procurement, manufacturing, etc.) and is sufficiently independent from cost and schedule.

- Has effective communication channels with other senior management positions.

- Has responsibility for approval of quality assurance plan(s) and manual(s), changes thereto, and interpretations thereof for the contractor.

- Has no other duties or responsibilities unrelated to quality assurance that would prevent full attention to quality assurance matters.

The persons responsible for directing and managing the overall quality assurance program have appropriate organizational position, responsibilities, and authority to exercise proper control over the quality assurance program. These individuals are free from non-quality assurance duties and, thus, can give full attention to assuring that the quality assurance program is being effectively implemented.

8.6.4 APPLICATION OF QUALITY ASSURANCE

The BWIP has operated under a formal documented quality assurance program from the commencement of site exploration (that phase during which it was determined if the BWIP site was suitable for site characterization) activities to date. The quality assurance program has evolved to support developing phases of the BWIP and to incorporate the most current revision of federally mandated requirements. The following sections describe how quality assurance was and will be applied.

8.6.4.1 Quality assurance during site exploration

Requirements for a formal, documented quality assurance program for DOE-RL and the BWIP participant contractors were established at the beginning of BWIP site exploration activities (December 1, 1977, to May 28, 1986). These requirements were initially stated in orders issued by DOE and redefined in the DOE-HQ Order 5700.6A (DOE, 1981) and DOE-RL Orders 5700.1 (DOE-RL, 1980) and 5700.1A (DOE-RL, 1983). These quality assurance documents established the requirement that activities affecting quality be defined and documented in appropriate directives, policies, procedures, and instructions, and applied to data gathering and other activities during site exploration. In response, the integrating contractor responsible for conducting the site exploration activities established quality assurance plans and quality assurance and technical procedures. Applicable quality assurance procedures (e.g., design and peer review) and technical implementing procedures were identified in the quality assurance plans (Rockwell, 1978; 1980; and 1982). Technical data-gathering techniques were documented in procedure manuals.

The quality assurance program for site exploration evolved from 1977 to 1986 and incorporated requirements in effect at the time work was performed. The program was modified as new requirements were imposed or requirements were adopted by the BWIP to improve program validity. During site exploration, data was gathered, which now that the BWIP has been selected for site characterization, will be used for characterization and to support possible license application. These data will be identified and qualified, against the current quality assurance program if required, on a case-by-case basis in accordance with approved procedures incorporating the requirements of Supplement 9 "Reliability of Data" to the Quality Assurance Plan for High-Level Radioactive Waste Repositories (DOE, 1986d).

8.6.4.2 Quality assurance during site characterization

This section consists of two parts. The first part describes the process by which items are determined to be important to safety or important to waste isolation (identified by the term Q list) and the criteria by which related activities are determined to be quality affecting (hereinafter referred to as

Quality Activities List), and the second part describes the graded quality assurance program to be applied to these and other items and activities associated with the BWIP.

8.6.4.2.1 Quality Level 1 items and activities

This subsection describes the methodology to be used by the BWIP in determining the structures, systems, and components important to safety and important to waste isolation for the mined geologic disposal system. Two lists will be generated as a result of implementation of this methodology: (1) the Q-list for items and (2) the Quality Activities List for activities related to site characterization (such as testing and data collection). Items and activities on the lists will be subject to the highest quality level of a formal quality assurance program required for site characterization and licensing of the geologic repository and will be subject to NRC licensing review and overview. While other items and activities will not be subject to regulatory control, the NRC may examine any item and activity not designated as Quality Level 1 to ensure that no items important to safety or important to waste isolation have been omitted from the Q-list and to ensure activities have not been omitted from the Quality Activities List.

The listing of Quality Level 1 items and activities will change over time, with a final list emerging at the completion of the NRC review of the DOE license application. During the period from the initiation of site characterization to license application, two milestones stand out: (1) the listing of Quality Level 1 items and activities to support the Site Characterization Plan (SCP) data-gathering and design efforts and (2) the listing of Quality Level 1 items and activities to support the license application design stage. A summary of the methodology to determine which items and activities are considered Quality Level 1 during the site characterization phase is described in this section. As site characterization and design activities progress to the point of allowing quantification of key input parameters, the license application design stage methodology will be implemented.

8.6.4.2.1.1 <u>Determination of items important to safety for the site characterization phase</u>

Structures, systems, and components that are important to safety are defined in 10 CFR 60.2 (NRC, 1987a):

> ...those engineered structures, systems and components essential to the prevention or mitigation of an accident that could result in a radiation dose to the whole body, or any organ, of 0.5 rem or greater at or beyond the nearest boundary of the unrestricted area at any time until the completion of permanent closure.

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Items important to safety must be on the Q-list to ensure that the design addresses their safety requirements and that appropriate quality assurance controls are applied. The basis for the systematic determination of the items important to safety for mined geologic disposal systems is a methodology developed for the DOE (DOE, 1986a).

The methodology used to develop a preliminary Q-list of items important to safety for surface and subsurface facilities is reported in the Basalt Repository Preliminary Q-List (WHC, 1987a).

Evaluation of repository design was based on the SCP repository conceptual design report (KE/PB, 1987) augmented by engineering experience with typical systems required at nuclear facilities. General hazards that would be encountered for these systems were evaluated as part of the selection process with emphasis on the potential for releases of radioactive materials. A general list of accident initiators, including both natural events and system failures, was developed. A screening process was used in performing a risk assessment for accident probabilities and consequences. Events judged incredible (i.e., a conservatively estimated probability less than 10^{-7} per year or a probability less than 10^{-5} per year with 95% confidence) or inconsequential (i.e., a maximum dose at or beyond the nearest boundary of the unrestricted area less than 0.1 rem) were screened from further consideration. The consequence screening value is based on the 10 CFR 60 (NRC, 1987a) limit of 500 mrem with an additional factor of conservatism, as requested by the methodology used in the analysis (DOE, 1986a). Likewise, the probability screening values are more conservative than required by the methodology. Items that were found to be essential to prevention or mitigation of significant off-site doses were listed as Q-list items. The use of screening values more conservative than required by the regulations should ensure that all potential items important to safety are placed on the Q-list.

The repository surface facilities important to safety were determined using an approach consistent with the methodology developed for the DOE and used for the repository subsurface facilities. However, because of the conceptual status of the surface facility design, the analysis used to determine Q-list items was conducted qualitatively rather than quantitatively. Subsequent evaluations for surface facilities will employ quantitative methods. The repository subsurface facilities important to safety were determined using the methodology developed for the DOE. The methodology was applied quantitatively and used event trees to perform a probabilistic risk assessment. The methodologies for these determinations are described more fully in the Basalt Repository Preliminary Q-List (WHC, 1987a).

Retrieval of the waste from the repository is a requirement of 10 CFR 60 (NRC, 1987a) and shall be treated in the same manner as waste emplacement. Much of the equipment needed for retrieval is expected to be the same as, or similar to, the equipment needed for waste emplacement. The procedures and criteria used to classify the items needed to emplace the waste shall be the same procedures and criteria used to determine if equipment needed to retrieve the waste should be included on the Q-list.

A list of those items determined to be important to safety and the rationale for this determination is presented in Section 6.1.4.

8.6.4.2.1.2 Determination of items important to waste isolation for the site characterization phase

From 10 CFR 60 (NRC, 1987a), it may be inferred that structures, systems, and components important to waste isolation would be those natural and engineered barriers that are relied on to inhibit "...the transport of radioactive material so that amounts and concentrations of this material entering the accessible environment will be kept within prescribed limits." These items must function in a certain way to meet the long-term isolation objective after repository closure.

In 10 CFR 60, paragraphs 60.112 and 60.113 (NRC, 1987a), the NRC has defined performance objectives for the repository after closure. The four performance objectives are related to the following performance measures:

- Containment by the set of waste packages.
- Rate of release of radionuclides from the engineered barrier system.
- Preemplacement groundwater travel time.
- Cumulative release to the accessible environment.

Consequently, structures, systems, and components important to waste isolation may include permanent shaft and borehole seals, engineered barriers (e.g., waste packages), and features of the natural site system. However, only the hardware portions of these barriers are Q-listed (DOE, 1986e). In addition, those items whose failure could have an impact on the engineered or natural barriers during a preclosure event, such that postclosure waste isolation performance could be compromised, are classified as important to waste isolation and Q-listed (DOE, 1986a).

Activities performed on the natural portions of these important-to-waste-isolation barriers are placed on a Quality Activities List. This list includes activities whose undertaking could adversely affect the performance of Q-listed items and barriers (e.g., drilling and blasting activities would need to be controlled so as to minimize the extent of the damaged rock zone and (or) degradation of the host rock impermeability and thus would be identified on the Quality Activities List). These activities will be conducted in conformance with Quality Level 1 requirements. Activities related to items important to waste isolation will be identified on the Quality Activities List as study plans are completed (DOE 1986e). The methodology for development of the Quality Activities List is provided in Section 8.6.4.2.2.

The designation of structures, systems, and components to be placed on the Q-list at the SCP design stage and all site characterization activities that are essential to adequately evaluate these items shall be based on technical judgment of the items required to comply with, or to demonstrate compliance with, the repository performance objectives as the repository

performance analyses are completed. A list of those items determined to be important to Waste Isolation is presented in Section 6.1.5 along with the rationale for this determination. More detailed discussion of the methodology used for identifying those items important to waste isolation is presented in Basalt Repository Preliminary Q-List (WHC, 1987a).

As the site characterization activities progress and the understanding of the BWIP site increases, changes to the Q-list may be appropriate or necessary. All site characterization tests and activities, therefore, must be planned carefully and must not only take into account the primary tests for the items initially placed on the Q-list, but also must include some contingency for items that may be added later to the Q-list. A conservative approach at the SCP design stage has been adopted to ensure that data necessary to demonstrate compliance with 10 CFR 60 (NRC, 1987a) are obtained and preserved in accordance with quality assurance requirements.

8.6.4.2.1.3 Quality Activities List

The Quality Activities List is a listing of activities that need to be controlled insofar as they affect the performance characteristics of a natural barrier important to waste isolation, the understanding of those performance characteristics, or the prediction of barrier performance. Study or test plans will identify those activities to be placed on the Quality Activities List.

Activities to be carried out during the site characterization phase have not all been identified or planned in detail. In addition, it is expected that plans for activities later in the site characterization program will be adjusted and modified on the basis of evaluation of earlier activities. For these reasons, criteria are described that allow for evaluation of any intended activities, for their impact on the natural barriers important to waste isolation, and for their importance to assessment of the waste isolation performance of the repository. Activities needing to be identified for the Quality Activities List fall into the four categories listed below.

- Activities that alter or modify the natural system barriers that are considered important to waste isolation. Examples of activities in this category include drilling the exploratory shaft and excavating underground openings in the repository isolation zone.

- Data collection activities that provide the basis for understanding and confirming the waste isolation performance characteristics of the natural barriers. These activities must be controlled to ensure the integrity and appropriateness of the data collected.

- The activities that comprise the actual model building that embodies the understanding of the long-term waste isolation performance of the natural barriers and that is the basis for the development of methods for predicting the waste isolation performance.

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- The performance assessment process of analytically evaluating the waste isolation performance of the natural barriers against the performance requirements of 10 CFR 60.113 (NRC, 1987a), including consideration of credible processes and events to which the barriers may be subjected.

Activities that fall within the categories identified above shall be evaluated for placement on the Quality Activities List. As study plans are developed, the quality level of each study and analysis will be determined. The Quality Activities List, and any changes thereto, will be identified in the semi-annual progress reports.

8.6.4.2.3 Graded quality assurance program

During site characterization of BWIP, a graded quality assurance program will be established and implemented. The purpose of a graded quality assurance program is to select the quality assurance measures to be applied to items and activities in the repository program consistent with their importance to safety, importance to waste isolation, and the achievement of program success. This selection process will be accomplished by deliberate planning and selective application of quality assurance requirements to the item or activity to be performed, with varying degrees of quality assurance applied depending on item function, complexity, consequence of failure, reliability, replicability of results, and economic considerations.

This approach involves (1) identifying those items and activities whose failure could cause undue risk to the public and facility personnel and (or) extended shutdown of the facility with critical economic losses and (2) ensuring that these items and activities are covered with a commensurate quality assurance program. On the other hand, an item whose failure or malfunction could result only in operational inconvenience or negligible economic loss may warrant only a quality inspection by the purchaser on delivery of the item. Between these two extremes, there are varying degrees of quality assurance to achieve the desired confidence in the quality of the completed item or activity.

The graded quality assurance approach set forth here provides flexibility in the selection of the quality level to be applied to an item or activity commensurate with the relative importance of the role or function assigned to the item or activity.

The requirements of this section are applicable to all items and activities required during geologic repository site characterization, facility and equipment construction, facility operation, performance confirmation, permanent closure, decommissioning, and dismantling of surface facilities.

The three quality assurance levels are defined as follows.

- Quality Level 1: The highest quality level available for assignment on geologic repository projects. The most stringent quality assurance requirements from Table 8.6-1 will apply to items on the Q-list and activities on the Quality Activities List in all phases of design, procurement, construction (fabrication), shipping, storage installation, or operations consistent with assuring that safety and (or) waste isolation objectives are met.

- Quality Level 2: The intermediate quality level available for assignment on geologic repository projects. Stringent quality assurance requirements from NQA-1-1986 (ANSI/ASME, 1986) will apply to items and activities not included under Quality Level 1 in those phases of design, procurement, construction (fabrication), shipping, storage, installation, and operations consistent with accomplishing DOE's mission objective.

- Quality Level 3: The lowest quality level available for assignment on geologic repository projects. This level is assigned to all items and activities included in the quality assurance program but not assigned Quality Levels 1 or 2. Quality assurance requirements from NQA-1 will apply as determined to items and activities not included in Quality Level 1 or 2 to provide assurance that good engineering, laboratory, and (or) workmanship practices are met consistent with the high quality expected of the repository.

The appropriate quality level for any item or activity is determined by the application of the decision criteria in Table 8.6-2. The basis for the selection of the quality level shall be documented.

Once a quality level is selected, the quality program criteria/requirements of Table 8.6-1 are applied. However, further grading beyond the selection of the quality level may be undertaken in accordance with approved procedures to select the specific criteria/requirements to be applied. This is accomplished by an evaluation by technical and quality assurance personnel of the scope and type of work involved and other factors, as appropriate, that may influence the selection of those criteria/requirements that are necessary and sufficient. The Q-list items and activities on the Quality Activities List shall meet the applicable requirements of 10 CFR 50, Appendix B (NRC, 1987b) and conditions of the NRC Quality Assurance Review Plan (NRC, 1984). The scope of work involved in completing an item or activity may be divided into subelements, and the criteria/requirements contained in Table 8.6-1 may be evaluated for application to these subelements.

For example, one Quality Level 1 (Q-list) item may involve an engineered piece of equipment that is very complex to design and manufacture, requiring special design controls, verification, and development tests in addition to special controls during manufacture. Thus, it may be subject to all the requirements, supplements, appendices, and other requirements set forth in Table 8.6-1 for Quality Level 1. On the other hand, another Quality Level 1 (Q-list) item may actually be a commercial off-the-shelf item that has a

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Table 8.6-1. Graded quality program requirements matrix (sheet 1 of 3)

Quality program requirements	Quality level			Quality program requirements	Quality level		
	1	2	3		1	2	3
NQA-1[a] BASIC REQUIREMENTS			(b)	NQA-1, 1986[a] SUPPLEMENTS			
1. Organization	X	X	--	S-1 Terms and Definitions	X	X	--
2. Quality Assurance Program	X	X	--	1S-1 Organization	X	--	--
3. Design Control	X	X	--	2S-1 Qualification of Inspection and Test Personnel	X	--	--
4. Procurement Document Control	X	X	--	2S-2 Qualification of Nondestructive Examination Personnel	X	--	--
5. Instructions, Procedures, and Drawings	X	X	--	2S-3 Qualification of Quality Assurance Program Audit Personnel	X	X	--
6. Document Control	X	X	--	2S-4 Supplementary Requirements for Personnel Indoctrination and Training	X	X	--
7. Control of Purchased Items and Services	X	X	--	3S-1 Design Control	X	X	--
8. Identification and Control of Items	X	X	--	4S-1 Procurement Document Control	X	--	--
9. Control of Processes	X	X	--	6S-1 Document Control	X	--	--
10. Inspection	X	X	--	7S-1 Control of Purchased Items and Services	X	X	--
11. Test Control	X	X	--	8S-1 Identification and Control of Items	X	--	--
12. Control of Measuring and Test Equipment	X	X	--	9S-1 Control of Processes	X	--	--
13. Handling, Storage, and Shipping	X	X	--	10S-1 Inspection	X	X	--
14. Inspection, Test, and Operating Status	X	X	--	11S-1 Test Control	X	--	--
15. Control of Nonconforming Items	X	X	--	12S-1 Control of Measuring and Test Equipment	X	--	--
16. Corrective Action	X	X	--	13S-1 Handling, Storage, and Shipping	X	--	--
17. Quality Assurance Records	X	X	--	15S-1 Control of Nonconforming Items	X	--	--
18. Audits	X	X	--	17S-1 Quality Assurance Records	X	X	--
10 CFR 50[c] APPENDIX B 18 QA CRITERIA	X			18S-1 Audits	X	X	--
NRC QA REVIEW PLAN	X						

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Table 8.6-1. Graded quality program requirements matrix (sheet 2 of 3)

Quality program requirements	Quality level		
	1	2	3
NQA-1-1986[a] APPENDICES			
1A-1 Organization	--	--	--
2A-1 Qualification of Inspection and Test Personnel	X	--	--
2A-2 Quality Assurance Programs	--	--	--
2A-3 Education and Experience of Lead Auditors	--	--	--
3A-1 Design Control	--	--	--
4A-1 Procurement Document Control	--	--	--
7A-1 Control of Purchased Items and Services	--	--	--
17A-1 Quality Assurance Records	--	--	--
18A-1 Audits	--	--	--
OGR QA PLAN SUPPLEMENTS			
S-1 Qualification of Personnel Performing and Verifying Activities Affecting Quality	X	X	--
S-2 Overview of Quality Assurance Activities	X	X	--
S-3 Q-List Methodology	X	X	--
S-4 Quality Assurance Records	X	X	--
S-5 Quality Assurance for (R&D) Experiments	X	X	--
S-6 (Reserved)			
S-7 Peer Review	X	X	--
S-8 Graded Quality Assurance	X	X	--
S-9 Reliability of Data	X	X	--
S-10 (Reserved for Waste Form)			

NOTE: OGR - Office of Geologic Repositories.
QA - Quality assurance.
[a]ANSI/ASME, 1986.
[b]Quality program requirements for Level 3 are established by the Basalt Waste Isolation Project and implemented on a case-by-case basis.
[c]NRC, 1987b.

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Table 8.6-1. Graded quality program requirements matrix (sheet 3 of 3)

Reference	Requirement description
NRC Review Plan Para. 2.5 (NRC, 1984)	1. Activity Planning--This applies to the application of graded approach of the QA program to the complexity commensurate with the importance of the work activities. Plans shall be developed and documented to describe how the activities shall be performed, the results expected, the major milestones, and other procedures to be used.
NRC Review Plan Para. 2.7 (NRC, 1984)	2. Management Assessment--This requirement applies to performance of annual management assessment to determine the scope, status, adequacy, and effectiveness of the QA program.
NRC Review Plan Para. 2.8 (NRC, 1984) Quality Assurance Plan for High-Level Radioactive Waste Repositories (DOE, 1986d)	3. Personnel Qualification and Certification--This requires that personnel who perform quality-related activities be properly trained, indoctrinated, and qualified. Personnel shall receive training in technical and quality assurance procedures. Management is required to monitor the performance of individuals involved in activities affecting quality and to determine the need for retraining and/or replacement.
NRC Review Plan Para. 3.8 (NRC, 1984)	4. Technical and Peer Reviews--These are the requirements that define technical and peer reviews and when they should be accomplished.
NRC Review Plan Para. 15.4 Para. 18.4 (NRC, 1984)	5. Trend Analysis--This requires that nonconformance reports be periodically analyzed to indicate quality trends and to help identify root causes of nonconformances. Results are to be reported to upper management for review and assessment.
DOE Order 5000.3 (DOE, 1984)	6. Unusual Occurrence Reporting--Contractors are required to report any significant event that results in any deviation from the planned or expected behavior of an activity or operation or course of events that has or could have significant programmatic (reliability, cost, or schedule), safety, health, or environmental impacts. Significant events are to be reported in accordance with DOE Order 5000.3.
NRC Review Plan Para. 2.2 (NRC, 1984) Quality Assurance Plan for High-Level Radioactive Waste Repositories (DOE, 1986d)	7. Software Control--These are detailed computer software quality assurance requirements that include validation, verification, code custodial and transfer requirements, and conformance with NUREG-0856 (NRC, 1986).
NRC Review Plan Para. 8.3 Para. 13.1, 13.2 (NRC, 1984)	8. Sample Handling--This requires that samples of geological media (e.g., rock, core, soil) be shipped, handled, and stored in accordance with special procedures that describe the control of the activities related to handling of samples.
Quality Assurance Plan for High-Level Radioactive Waste Repositories (DOE, 1986d)	9. Data Acquisition, Verification, and Analysis--This requires that data and information that is received from literature searches be validated from the technical adequacy perspective and for correct application.
Quality Assurance Plan for High-Level Radioactive Waste Repositories (DOE, 1986d)	10. Reporting and Submittals--These are requirements that identify the types of reports and the frequency of submittals. Examples: Audit Reports and Schedule Revisions per OGR-B-3 -- each report, and each audit schedule revision Surveillance Reports -- each report Summary Reports -- quarterly (per OGR/B-3) Unusual Occurrence Reports -- Records Management Plan --
NRC Review Plan Para. 3.10 (NRC, 1984)	11. Configuration Control--A configuration system shall be established at the earliest practical time to ensure that design changes are analyzed and properly identified and documented.
Quality Assurance Plan for High-Level Radioactive Waste Repositories (DOE, 1986d)	12. Records Management--Records shall be stored, identified, and reviewed as described in a Records Management Plan.

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Table 8.6-2. Decision criteria for determining quality levels of items and activities (sheet 1 of 3)

Categories of statements of work	Quality level		
	1	2	3
Items (hardware)			
• Public health and safety considerations			
- Is the item on the Q-list?	X		
• DOE programmatic objectives considerations			
- Is the item intended to control radiation exposure or release levels and (or) effluent radioactivity within the limits prescribed by 10 CFR 20 (NRC, 1987c)?		X	
- Failure or malfunction of the item could cause the following potential impact on DOE mission objectives:			
• Impact on cost or schedule impact >10,000 K.		X	
• Impact on cost or schedule impact ≤10,000 K.			X
• Worker health and safety considerations			
- Failure or malfunction of the item could have potential impact on the radiological or nonradiological health and safety of the workers.		X	
• Lead time and cost considerations			
- Does procurement of the item involve long lead time and/or is the item extremely costly?		X	
• ASME-BPVC applicability considerations			
- Section III applies		X	
- Section VIII applies.		X	
Activities			
• Computer software modeling/development			
- Are the computer models used to support an item on the Q-list?	X		
- Do the computer models and codes supply data to support a licensing decision such as performance assessment?	X		
- Are the computer models complex, and are peer or technical reviews required?		X	
- Does the work support critical DOE mission documents?		X	
- If the collected data or records were lost/discarded or of indeterminate quality, the following would occur:			
• The quality of a Q-listed item or Quality Activity list activity would be indeterminate.	X		
• Repetition resulting in cost or schedule impact >10,000 K.		X	

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Table 8.6-2. Decision criteria for determining quality levels of items and activities (sheet 2 of 3)

Categories of statements of work	Quality level		
	1	2	3
• Repetition would result in a cost or schedule impact ≤10,000 K.			X
- Is the computer program only used for such tasks as data sorting and collation?			X
• Field testing, data acquisition, data analysis, and reports			
- Are the data utilized to support an engineering design criterion for a Q-list item?	X		
- Do the data support a major licensing document?	X		
- Will the data become part of the technical data base needed to support licensing?	X		
- Does the work provide input to critical DOE mission documents?		X	
- If the collected data or records were lost/discarded or of indeterminate quality, the following would occur:			
• The quality of a Q-listed item or Quality Activity List activity would be indeterminate.	X		
• Repetition resulting in cost or schedule impact >10,000 K.		X	
• Repetition resulting in cost or schedule impact ≤10,000 K.			X
• Storage of records/samples			
- Do records/samples support licensing activities?	X		
- Do records/samples support items on the Q-list?	X		
- Do records/samples support critical DOE mission documents?		X	
- If the collected data or records/samples were lost/discarded or of indeterminate quality, the following would occur:			
• The quality of a Q-listed item or Quality Activity List activity would be indeterminate.	X		
• Repetition resulting in cost or schedule impact >10,000 K.		X	
• Repetition with cost or schedule impact ≤10,000 K.			X
• Historical or background studies and reports			
- Will the information produced be used in a licensing document?	X		
- Do the studies support a computer model or design criterion for a Q-list item?	X		
- Does the work support critical DOE mission documents?		X	
- If the collected data or records were lost/discarded or of indeterminate quality, the following would occur:			

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Table 8.6-2. Decision criteria for determining quality levels of items and activities (sheet 3 of 3)

Categories of statements of work	Quality level		
	1	2	3
• Repetition resulting in cost or schedule impact >10,000 K.		X	
• Repetition with cost or schedule impact ≤10,000 K.			X
• Environmental/socioeconomic studies and reports			
- Do the reports or studies provide critical information to support requirements of the Nuclear Waste Policy Act of 1982 (NWPA, 1983)?	X		
- Will the reports or studies be used for major portions of a licensing document?	X		
- Does the work support DOE mission documents?		X	
- If the collected data or records were lost/discarded or of indeterminate quality, the following would occur:			
• Repetition resulting in major cost or schedule impact >10,000 K.		X	
• Repetition with minor cost or schedule impact ≤10,000 K.			X
• Laboratory experimental (scoping) or testing/analysis and reports			
- Will the data results be used to support licensing activities?	X		
- Does the experimental testing provide analytical data to support functional design bases?	X		
- If the collected data or records were lost/discarded or of indeterminate quality, the following would occur:			
• The quality of a Q-listed item or Quality Activity List activity would be indeterminate.	X		
• Repetition resulting in cost or schedule impact >10,000 K.		X	
• Repetition with cost or schedule impact ≤10,000 K.			X
• Construction/manufacturing activities			
- Is the construction/manufacturing activity supporting a Q-list structure, system, or component?	X		
- Is the activity intended to control radiation exposure or release levels and (or) effluent radioactivity within the limits prescribed by 10 CFR 20 (NRC, 1987c)?		X	
- Is the construction/manufacturing activity supporting a highly critical item with a high cost of repair or replacement?		X	
- Is the system important for reliability?		X	

NOTE: DOE = U.S. Department of Energy.
ASME-BPVC = American Society for Mechanical Engineers-Boiler Pressure Vessel Code.

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proven design, is easy to build, has a good quality history, and is well within the state of the art. The appropriate quality program requirements for this second example may be fewer than for the first example involving the newly engineered piece of equipment, and several of the criteria/requirements listed in Table 8.6-1 may not be required to ensure that appropriate quality is achieved.

The depth of coverage and comprehensiveness of any given quality program criteria/requirement within a quality level may be additionally increased, decreased, or modified as deemed necessary for each item or activity. The technical and quality assurance personnel shall evaluate each item and activity to determine the depth and comprehensiveness of coverage within each applicable criterion and (or) requirement appropriate for that item or activity. Factors to be considered in making this determination include complexity of design or fabrication, uniqueness of the item or activity, need for controls over special processes or tests, ability to demonstrate functional compliance by inspection or test, and the quality history of the item or activity. Appendix 4A-1 of NQA-1-1986 (ANSI/ASME, 1986) may also be used as guidance in applying graded quality assurance.

For example, NQA-1-1986 Basic Requirement 10, Supplement 10S-1 (ANSI/ASME, 1986), and 10 CFR 50 Appendix B, Criterion 10 (NRC, 1987b), may all apply to sealing a repository shaft and welding a shaft liner. Both processes require inspections to verify conformance with design requirements. As it may be difficult to verify that the shaft sealing has been properly performed after placement, continuous surveillance may be appropriate. Conversely, welding is normally verified after completion, and only normal examinations and inspections of completed weldments may be necessary.

Written justification shall be provided for cases where deviations were made from NQA-1-1986 (ANSI/ASME, 1986) basic requirements, supplementary requirements, appendixes, and (or) quality assurance criteria of 10 CFR 50, Appendix B (NRC, 1987b), or other requirements specified in Table 8.6-1 as being necessary and sufficient for a certain quality level. Deviations are defined as additions of specified requirements, deletion of specified requirements, or modifications to specified requirements. The written justification for additions is necessary to support and explain the basis for the additional quality assurance requirements and, thus, justify the corresponding additional cost and effort.

These quality levels, presented in descending order, have decreasing scope of quality program criteria/requirements. This is evident in the matrix comparison of quality levels shown in Table 8.6-1.

A description of each quality level and guidance for application of each level follows:

1. Quality Level 1

   Description. This is the highest quality level available and requires the responsible organization to implement a quality

assurance program that meets, as a minimum, all applicable requirements of the BQARD (DOE-RL, 1987a). Quality Level 1 programs require quality planning, preparation of a quality assurance manual/plan and supporting administrative and technical procedures, adherence to procedures and drawings, personnel qualification training programs, documentation of activities performed and results obtained and comprehensive review, inspection, management assessment, verification, surveillance, and auditing activities.

Quality Level 1 programs shall meet the criteria/requirements listed in Table 8.6-1 for Quality Level 1, as a minimum, unless appropriate written justification for any deviation is provided. Other specific requirements that are unique to the item or activity may be specified during the quality level selection process. Certain items and activities with potential for inclusion on the Q-list or Quality Activities List, respectively, may be identified and (or) directed by the DOE to be treated as a Quality Level 1.

Application. Quality Level 1 shall be applied to all items that have been identified as important to safety or important to waste isolation (Q-list items). Activities covered under Quality Level 1 are those on the Quality Activities List and may include site selecting, designing, fabricating, purchasing, handling, shipping, storing, cleaning, erecting, installing, emplacing, inspecting, testing, operating, maintaining, monitoring, repairing, modifying, decommissioning, and site characterization.

2. Quality Level 2

Description. This is the second highest level available for assignment to items and activities on geologic repository projects. Responsible organizations are required to implement quality assurance programs. A quality assurance manual/plan and supporting procedures are required. The same basic NQA-1-1986 quality assurance requirements (ANSI/ASME, 1986) that apply to Quality Level 1 also apply to Quality Level 2. However, 10 CFR 50, Appendix B (NRC, 1987b), and the NRC Review Plan (NRC, 1984) do not apply to Quality Level 2. Fewer NQA-1-1986 supplemental requirements apply to Quality Level 2 with corresponding reductions in quality assurance controls.

Quality Level 2 programs shall meet the criteria/requirements listed in Table 8.6-1 for Quality Level 2, as a minimum, unless appropriate written justification for any deviation is provided. Other specific requirements unique to the item or activity may be specified by the organization responsible for quality level selection.

Application. Quality Level 2 shall be applied to those items that are not Q-list items and activities not on the Quality Activities List but are of major importance to the attainment of DOE programmatic objectives. Quality Level 2 is also to be applied to items

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and activities that have potential impact on public and occupational radiological health and safety under 10 CFR 20 (NRC, 1987c) and to items involving a significant number of field and laboratory investigations and complex manufacturing, assembly, and construction processes.

3. Quality Level 3

Description. This is the lowest quality level available for assignment. Quality Level 3 items and activities may be required to meet appropriate quality and administrative requirements as determined on a case-by-case basis. The quality requirements to be met for each item or activity, including any required documentation, shall be identified and justified. Quality Level 3 items and activities generally require the use of good management, engineering, or laboratory work practices to prepare them for their intended use.

Application. Quality Level 3 shall be applied to those items and activities that do not meet the criteria for Quality Level 1 or 2. This quality level shall be applied to items that can be inspected for acceptance on completion or delivery or to activities that can be accepted by evaluation of a final report. When deemed appropriate, the requirement to obtain a "Certificate of Conformance" from the supplier may be invoked by the organization responsible for quality level selection. Additional requirements may be implemented, as deemed necessary, to effect more uniform management controls.

Typical items and activities that shall be covered by this quality level include the following:

a. Items that are noncomplex and are normally considered commercially available standard hardware.

b. Activities that are routine or purely developmental in nature and will not produce data or results that will be used for design, environmental, or licensing applications.

8.6.5 QUALITY ASSURANCE ADMINISTRATIVE PROCEDURES

This section lists the quality assurance administrative procedures for the DOE-RL, Westinghouse BWIP (the integrating contractor), Kaiser Engineers, Inc./Parsons Brinckerhoff Quade & Douglas, Inc. (the architect-engineer), and Morrison-Knudsen (the construction manager), as contained in their quality assurance manuals for site characterization activities (i.e., those activities

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commencing after May 28, 1986). Quality assurance administrative procedures are those that define and direct controls and control systems making up the BWIP quality assurance program. These procedures are listed by the criterion they implement with the responsible BWIP organization as a subheading.

Criterion 1.0 - Organization

- The U.S. Department of Energy-Richland Operations Office.

BP 1.1	Organization
BP 1.7	Commitment/Action Item Tracking
BP 1.8	Correspondence Control
BP 1.11	Stop Work

- Westinghouse Hanford Company, Civilian Waste Management Division, Basalt Waste Isolation Project (integrating contractor).

PMPM ORG-1.1	Westinghouse BWIP Organization and Responsibilities
PMPM 04-103	BWIP Quality Assurance Surveillance Report
PMPM 04-105	Nonconformance Reports
PMPM 04-106	Construction Nonconformance Reports
PMPM 04-115	Stop Work Order
PMPM 04-116	Resolution of Disputes with Quality Assurance
PMPM 04-120	Quality Concerns Program
PMPM 04-121	Graded Quality Assurance
PMPM 06-101	Major Participant Interface Control
PMPM 13-106	Administration of Qualification and Training
PMPM 14-102	Software Change Control

- Morrison-Knudsen (construction manager) (M-K, 1986).

QAP 1.1	Organization
QAP 1.2	Stop Work Order

- Kaiser Engineers, Inc./Parsons Brinckerhoff Quade & Douglas, Inc. (architect-engineer) (KE/PB, 1986).

PP 1.2	Project Organization

Criterion 2.0 - Quality Assurance Program

- U.S. Department of Energy-Richland Operations Office

BP 2.1	Quality Assurance Program Assessment
BP 2.2	Work Progress and Design Reviews
BP 2.5	Personnel Training
BP 2.7	Appeals on Quality Concerns
BP 2.8	Control and Release of Licensing Documents
BP 2.10	Reporting of Significant Deficiencies
BP 2.11	Review of Quality Affecting Source Documents (later)

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- Westinghouse Hanford Company, Civilian Waste Management Division, Basalt Waste Isolation Project.

PMPM ORG-1.1	Westinghouse BWIP Organization and Responsibilities
PMPM 01-114	Project Management and Work Process Control
PMPM 02-112	Construction Acceptance Test Control
PMPM 02-130	Control of Special Processes
PMPM 04-104	Quality Assurance Audits
PMPM 04-108	Inspection Activities
PMPM 04-111	Quality Assurance Trend Analysis
PMPM 04-121	Graded Quality Assurance
PMPM 07-108	Control of Standards and Measuring and Test Equipment
PMPM 07-119	Data Collection Test Control
PMPM 08-133	Document Control
PMPM 13-106	Administration of Qualification and Training
PMPM 14-102	Software Change Control

- Morrison-Knudsen (construction manager).

QAP 2.1	Quality Assurance Program
QAP 2.2	Indoctrination and Training
QAP 2.3	Qualification and Certification of Inspection Personnel
QAP 2.4	Qualification and Certification of Audit Personnel
QAP 2.5	Management Reviews
QAP 2.6	Qualification and Certification of Nondestructive Examination Personnel

- Kaiser Engineers, Inc./Parsons Brinckerhoff Quade & Douglas, Inc. (architect-engineer).

PP 1.3	Management Assessment of QA and Related Activities
PP 2.1	Orientation and Training
PP 2.3	Procedure Preparation and Control
PP 2.6	Corrective Action
PP 2.9	Audits
PP 6.26	Graded Quality Assurance

Criterion 3.0 - Design Control

- U.S. Department of Energy-Richland Operations Office.

BP 3.1	Project Reviews
BP 3.2	Disposition of Change Requests
BP 3.3	Peer Review
BP 3.4	Graded Quality Assurance
BP 3.5	Data Qualification Activities
BP 3.6	Readiness Review (later)

- Westinghouse Hanford Company, Civilian Waste Management Division, Basalt Waste Isolation Project.

PMPM 02-126	Design Control Process
PMPM 03-102	Peer Review
PMPM 04-105	Nonconformance Reports
PMPM 04-106	Construction Nonconformance Reports
PMPM 04-122	Corrective Action Reports
PMPM 14-102	Software Change Control

- Morrison-Knudsen (construction manager).

QAP 3.1	Design/Field Changes

- Kaiser Engineers, Inc./Parsons Brinckerhoff Quade & Douglas, Inc. (architect-engineer).

PP 6.0	Conduct of Design Activities
PP 6.1	Control of Design Input
PP 6.8	Document Control
PP 6.10	Engineering Disposition of CNCRs
PP 6.19	Review Comment Record Processing
PP 6.20	Preparation, Disposition and Control of Nonconformance Reports
PP 6.22	Peer Review
PP 6.23	QA Record Designation and Control
PP 6.24	Design Interface Control
PP 6.26	Graded QA

<u>Criterion 4.0 - Procurement Document Control</u>

- U.S. Department of Energy-Richland Operations Office.

BP 4.1	Preparation and Control of Procurement Documents
BP 4.2	Contractor Initiated Procurements

- Westinghouse Hanford Company, Civilian Waste Management Division, Basalt Waste Isolation Project.

PMPM 06-101	Major Participant Interface Control
PMPM 06-115	Procurement Management System
PMPM 06-116	Procurement Document Control
PMPM 06-117	Major Project Participant Procurement Interface Activities
PMPM 07-119	Data Collection Test Control

- Morrison-Knudsen (construction manager).

QAP 4.1	Procurement

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Criterion 5.0 - Plans, Instructions, Procedures, and Drawings

- U.S. Department of Energy-Richland Operations Office.

  BP 5.1 Procedure Development

- Westinghouse Hanford Company, Civilian Waste Management Division, Basalt Waste Isolation Project.

  ORG. 1.1 WHC BWIP Organization and Responsibilities
  PMPM 02-126 Design Control Process

- Morrison-Knudsen (construction manager).

  QAP 5.1 Preparation, Revision and Approval of Quality Assurance Procedures and Instructions
  QAP 5.2 Preparation, Issue and Control of Work Procedures

- Kaiser Engineers, Inc./Parsons Brinckerhoff Quade & Douglas, Inc. (architect-engineer).

  PP 2.1 QA Orientation/Indoctrination/Qualification and Training
  PP 2.3 Procedure Preparation and Control

Criterion 6.0 - Document Control

- U.S. Department of Energy-Richland Operations Office.

  BP 6.1 Preparation and Release of AMC Documents
  BP 6.2 Controlled Documents Issued to AMC Staff
  BP 6.3 Review and Approval of External Documents

- Westinghouse Hanford Company, Civilian Waste Management Division, Basalt Waste Isolation Project.

  PMPM 08-133 Document Control

- Morrison-Knudsen (construction manager).

  QAP 6.1 Document Control

- Kaiser Engineers, Inc./Parson Brinckerhoff Quade & Douglas, Inc. (architect-engineer).

  PP 2.3 Procedure Preparation and Control
  PP 6.1 Control of Design Input
  PP 6.8 Document Control

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Criterion 7.0 - Control of Purchased Material Equipment and Services

- U.S. Department of Energy-Richland Operations Office.

BP 7.1	Supplier Evaluation, Selection, and Verification
BP 7.2	Supplier Furnished Records

- Westinghouse Hanford Company, Civilian Waste Management Division, Basalt Waste Isolation Project.

PMPM 04-105	Nonconformance Reports
PMPM 04-106	Construction Nonconformance Reports
PMPM 04-111	Quality Assurance Trend Analysis

- Morrison-Knudsen (construction manager)

QAP 7.1	Supplier Qualification
QAP 7.2	Source Verification

Criterion 8.0 - Identification and Control of Items

- U.S. Department of Energy-Richland Operations Office.

NA

- Westinghouse Hanford Company, Civilian Waste Management Division, Basalt Waste Isolation Project.

PMPM 07-118	Identification and Control of Samples
PMPM 07-120	Control of Data Gathering Equipment, Components and Materials
PMPM 07-121	Inspection, Test, and Operating Status Indicators

- Morrison-Knudsen (construction manager).

QAP 8.1	Identification and Control of Items and Samples

Criterion 9.0 - Control of Special Processes

- U.S. Department of Energy-Richland Operations Office.

NA

- Westinghouse Hanford Company, Civilian Waste Management Division, Basalt Waste Isolation Project.

PMPM 02-130	Control of Special Processes
PMPM 04-103	Surveillance Activities
PMPM 04-108	Inspection Activities
PMPM 04-104	Quality Assurance Audits

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- Morrison-Knudsen (construction manager).

  QAP 9.1 Control of Special Processes

Criterion 10.0 - Inspection

- U.S. Department of Energy-Richland Operations Office,

  NA

- Westinghouse Hanford Company, Civilian Waste Management Division, Basalt Waste Isolation Project.

ORG. 1.1	WHC BWIP Organization and Responsibilities
PMPM 01-111	BWIP Action Tracking System
PMPM 04-103	Surveillance Activities
PMPM 04-105	Nonconformance Reports
PMPM 04-106	Construction Nonconformance Reports
PMPM 04-108	Inspection Activities
PMPM 04-111	Quality Assurance Trend Analysis
PMPM 07-119	Data Collection Test Control
PMPM 04-115	Stop Work Order
PMPM 04-122	Corrective Action Report
PMPM 08-133	Document Control
PMPM 13-106	Administration of Qualification and Training

- Morrison-Knudsen (construction manager).

  QAP 10.1 Instructions for the Conduct of Inspections

Criterion 11.0 - Test Control

- U.S. Department of Energy-Richland Operations Office.

  NA

- Westinghouse Hanford Company, Civilian Waste Management Division, Basalt Waste Isolation Project.

ORG. 1.1	WHC BWIP Organization and Responsibilities
PMPM 02-112	Construction Acceptance Test Control
PMPM 04-103	Surveillance Activities
PMPM 04-104	Quality Assurance Audits
PMPM 04-105	Nonconformance Reports
PMPM 04-106	Construction Nonconformance Reports
PMPM 04-108	Inspection Activities
PMPM 07-108	Control of Standard(s) and Measuring and Test Equipment
PMPM 07-119	Data Collection Test Control
PMPM 08-103	BWIP Records Management System
PMPM 11-103	Unusual Occurrence Reporting System

9 2 1 2 5 5 1 1 7 3

PMPM 13-106	Administration of Qualification and Training
PMPM 14-102	Software Change Control

- Morrison-Knudsen (construction manager).

QAP 11.1	Test Control (TBI)

Criterion 12.0 - Control of Measuring and Test Equipment

- U.S. Department of Energy-Richland Operations Office.

NA

- Westinghouse Hanford Company, Civilian Waste Management Division, Basalt Waste Isolation Project.

PMPM 07-108	Control of Standard(s) and Measuring and Test Equipment
PMPM 04-105	Nonconformance Reports
PMPM 04-106	Construction Nonconformance Reports
PMPM 04-122	Corrective Action Reports
PMPM 06-115	Procurement Management System

- Morrison-Knudsen (construction manager).

QAP 12.1	Calibration, Control, and Use of Measuring and Test Equipment

Criterion 13.0 - Handling, Shipping, and Storage

- U.S. Department of Energy-Richland Operations Office.

NA

- Westinghouse Hanford Company, Civilian Waste Management Division, Basalt Waste Isolation Project

PMPM 06-101	Major Participant Interface Control
PMPM 06-117	Major Project Participant Procurement Interface Control
PMPM 13-106	Administration of Qualification and Control of Samples
PMPM 06-119	Shipping and Storage Control
PMPM 07-118	Identification and Control of Samples

- Morrison-Knudsen (construction manager).

QAP 13.1	Handling, Storage, and Preservation of Equipment and Materials

9 2 1 2 5 5 1 1 7 4

Criterion 14.0 - Inspection Test and Operating Status

- U.S. Department of Energy-Richland Operations Office.

  NA

- Westinghouse Hanford Company, Civilian Waste Management Division, Basalt Waste Isolation Project.

PMPM 04-105	Nonconformance Reports
PMPM 04-108	Inspection Activities
PMPM 04-106	Construction Nonconformance Reports
PMPM 07-121	Inspection, Test and Operating Status

- Morrison-Knudsen (construction manager).

QAP 14.1	Inspection and Examination Status
QAP 14.2	Testing, Operating, and Safety Status

Criterion 15.0 - Control of Nonconforming Items

- U.S. Department of Energy-Richland Operations Office.

BP 15.1	Processing Contractor NCRs and Unusual Occurrences
BP 15.2	Trend Analysis

- Westinghouse Hanford Company, Civilian Waste Management Division, Basalt Waste Isolation Project.

PMPM 01-111	BWIP Action Tracking System
PMPM 04-105	Nonconformance Control System
PMPM 04-106	Construction Nonconformance Reports
PMPM 04-111	Quality Assurance Trend Reporting
PMPM 04-122	Corrective Action Report
PMPM 07-121	Inspection, Test, and Operating Status Indicators
PMPM 11-103	Unusual Occurrence Reporting System

- Morrison-Knudsen (construction manager).

QAP 15.1	Control of Nonconformances

- Kaiser Engineers, Inc./Parsons Brinckerhoff Quade & Douglas, Inc. (architect-engineer).

PP 6.10	Engineering Disposition of Construction Nonconformance Reports
PP 6.20	Preparation, Disposition, and Control of Nonconformance Reports
PP 6.25	Unusual Occurrence Reporting

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Criterion 16.0 - Corrective Action

- U.S. Department of Energy-Richland Operations Office.

  BP 16.1 Corrective Action

- Westinghouse Hanford Company, Civilian Waste Management Division, Basalt Waste Isolation Project

  PMPM 01-111 BWIP Action Tracking System
  PMPM 04-104 Quality Assurance Audits
  PMPM 04-105 Nonconformance Reports
  PMPM 04-106 Construction Nonconformance Reports
  PMPM 04-111 Quality Assurance Trend Reporting
  PMPM 04-122 Corrective Action Report
  PMPM 11-103 Unusual Occurrence Reporting System

- Morrison-Knudsen (construction manager).

  QAP 16.1 Corrective Action Request

- Kaiser Engineers, Inc./Parsons Brinckerhoff Quade & Douglas, Inc. (architect-engineer).

  PP 2.6 Corrective Action Reports
  PP 2.9 Audits
  PP 6.20 Preparation, Disposition, and Control of Nonconformance Reports

Criterion 17.0 - Quality Assurance Records

- U.S. Department of Energy-Richland Operations Office.

  BP 17.1 Quality Records

- Westinghouse Hanford Company, Civilian Waste Management Division, Basalt Waste Isolation Project.

  PMPM 08-103 BWIP Records Management System

- Morrison-Knudsen (construction manager).

  QAP 17.1 Quality Assurance Records

- Kaiser Engineers, Inc./Parsons Brinckerhoff Quade & Douglas, Inc. (architect-engineer).

  PP 6.1 Control of Design Input
  PP 6.8 Document Control
  PP 6.23 QA Record Designation and Control

9 2 1 2 5 5 1 1 7 6

Criterion 18.0 - Audits

- U.S. Department of Energy-Richland Operations Office.

BP 18.1	Audit and Surveillance Planning
BP 18.4	Auditor Qualifications
BP 18.5	Surveillance of Project Activities
BP 18.6	Quality Assurance Audits

- Westinghouse Hanford Company, Civilian Waste Management Division, Basalt Waste Isolation Project.

PMPM 04-104	Quality Assurance Audits
PMPM 04-111	Trend Analysis
PMPM 08-103	BWIP Records Management System
PMPM 13-106	Administration of Qualification and Training

- Morrison-Knudsen (construction manager).

QAP 18.1	Quality Assurance Audits

- Kaiser Engineers, Inc./Parsons Brinckerhoff Quade & Douglas, Inc. (architect-engineer).

PP 2.2	Quality Assurance Surveillance of Project Activities
PP 2.6	Corrective Action Report
PP 2.9	Audits

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8.6.6 DETAILED TECHNICAL PROCEDURES AND TEST PLANS

In accordance with requirements of the Systems Engineering Management Plan for the Basalt Waste Isolation Project (DOE-RL, 1986a), all technical work conducted as part of the BWIP will be performed following documented implementation plans and in accordance with technical procedures. The implementation plans for site characterization activities will be described and documented in appropriate study plans, which in addition to presenting an overview of specific field activities, will identify discipline-specific implementing technical procedures. Each study plan will discuss the study rationale, information requirements, technical design of study and selection rationale, schedule and milestones, organization and management, and quality assurance.

Detailed technical implementing procedures (detailed step-by-step instructions that are developed by qualified technical personnel in accordance with the requirements specified in administrative quality assurance procedures (see Section 8.6.5)) are being developed to support the study plans for the actual performance of the individual technical activities associated with site characterization. The procedures will be described in detail in separate technical procedures documents associated with specific study plans.

Although not all the study plans and detailed technical procedures will be completed at the time of submittal of the Site Characterization Plan, those that are completed are identified and discussed in Section 8.3.

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*A decision on July 17, 1987, by the U.S. Court of Appeals for the First Circuit has required the EPA to reconsider its postclosure standards (Subpart B) in 40 CFR 191. Consequently, the standards in 40 CFR 191 may be subject to revision in the future.

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SITE CHARACTERIZATION PLAN

Chapter 8 - SITE CHARACTERIZATION PROGRAM

Section 8.7
Decontamination and Decommissioning Plans for the Candidate Site

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8.7 DECONTAMINATION AND DECOMMISSIONING PLANS FOR THE CANDIDATE SITE

The Nuclear Waste Policy Act of 1982 (NWPA, 1983, Section 113(b)(1)(A)(ii)) provides for decontaminating and decommissioning the candidate repository at the Hanford Site in Washington State if site characterization activities determine the candidate site to be unsuitable for a nuclear waste respository. Only after such a determination would specific plans be developed to address decontamination and decommissioning issues. Because no high-level radioactive materials are expected to be used during site characterization and any radioactive tracer material would have a short half-life, no decontamination plans will be required. Specific decommissioning plans would be developed in consultation with the involved state and affected Indian tribes.

Analogous, but much larger scale, reclamation activities associated with deep shaft and surface strip mines are well documented. There is a large body of experience in these activities over a long period of time. Because it is not known at what point, if any, a candidate site might be declared unsuitable, it is not known to what extent a site will have been characterized. Therefore, it would not serve any purpose to prepare decommissioning or decontamination plans in great detail. Rather, typical activities that might be employed will be discussed in this section.

Decontamination (Section 8.7.1) provides steps that might be taken to retrieve any radioactive material used at the repository site during site characterization.

Closure and decommissioning (Section 8.7.2) provide probable steps for the closure of the following:

- Test boreholes.
- Two main exploratory shafts.
- Any drifts.
- Other underground features of the site characterization activities.

All surface facilities (e.g., drill pads, utility sheds, mud pits, parking lots, etc.) also will be closed and removed. Borehole sealing and shaft sealing concepts for the repository are described in Section 6.2.8.

Plans for mitigation (Section 8.7.3) covers steps that would be taken to eliminate any significant environmental impacts should site characterization activities cease.

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8.7.1 DECONTAMINATION

The plans for site characterization activities do not include the use of high-level radioactive materials (NWPA, 1983, Section 113(c)(2)). Radioactive sources used in geophysical logging at the Exploratory Shaft Facility are designed to be fully contained and retrievable (DOE, 1985). If necessary, these sources could be totally removed from the environment by the over-coring methods used to perform the various tests described in Section 8.3.1.3. Radioactive materials that could be used as tracer material in the geochemical characterization (see Section 8.3.1.4.4) have short half-lives ranging from several hours to tens of days (DOE, 1985) and, therefore, pose no environmental impact. In many instances, biodegradable organic tracers or inorganic tracers would be used in lieu of radioactive tracers. The radioactive marker that may be added to the chemical seal ring during construction of the shaft (see Section 8.4.2.1.1) has a half-life of less than 10 d and has no environmental impact. Therefore, no decontamination is expected to be required after site characterization (DOE, 1985).

8.7.2 CLOSURE AND DECOMMISSIONING

What will eventually happen to the candidate site depends on site characterization results and many decisions that could lead to the four identifiable alternatives discussed below.

1. If the Hanford Site is determined to be suitable and is subsequently picked as the first repository, then the Exploratory Shaft Facility would be incorporated into the repository as discussed in Section 6.2. The Exploratory Shaft Facility would be modified for the initial phase of repository construction.

2. If the Hanford Site is determined to be suitable but is not chosen as the first site for the repository, it would not be decommissioned until a final decision is made on the second repository. This would require maintenance of the facility in a ready, or caretaker, status (e.g., ventilation and pumping systems would remain in operation; some testing would be continued).

3. If the Hanford Site is determined to be unsuitable for the repository and an alternative use is proposed for the Exploratory Shaft Facility, resulting closure and decommissioning plans would depend on whether this use was either near term or long term. These uses would be as follows:

   - A near-term alternate use for the Exploratory Shaft Facility would require limited standby decommissioning until the alternate program could be started. The ventilation and pumping system would remain in operation. Periodic maintenance would preserve the structural integrity of the facility. Adequate surface physical security would be retained to prevent unauthorized access.

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- A long-term alternate use for the Exploratory Shaft Facility would require a cost benefit analysis to determine if it would be more economical to turn off the ventilation and pumping systems until the underground facility is needed. At the time of use, the water filling the facility would be pumped out. Prior to turning off these systems, utilities and all underground salvageable material and equipment would be removed. The shafts would then be sealed at the surface. Surface facilities needed for the new use would remain in place in a "mothballed" condition. Adequate security would be required to protect the mothballed surface facilities.

There are no known near-term or long-term alternative uses identified or implied by these alternatives.

4. If the Hanford Site is determined to be unsuitable and no alternative uses are identified, closure and decommissioning would begin. The exploratory shafts and exploratory boreholes would be sealed to maintain aquifer isolation, and the surface facilities would be decommissioned. The underground openings in the Cohassett flow would be backfilled only if there were unusual circumstances where caving of the back (top) of the drift would change the hydrologic regime of the involved area.

Closure and decommissioning will be discussed in detail in the following sections on boreholes (surface and subsurface), shafts, subsurface openings, surface facilities, earthworks, surface emplacements, and utilities.

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8.7.2.1 Surface borehole closure and decommissioning

The location and characteristics of all surface drill holes at and near the Hanford Site were identified in Section 1.6. The boreholes used for hydrologic characterization were further described in Section 3.9. The locations of those key Basalt Waste Isolation Project (BWIP) boreholes presently drilled in the controlled area study zone are shown in Figure 8.7-1. Any additional boreholes planned for site characterization activities were described in Section 8.3.1. Even though these are program-related boreholes, only those not identified for future use by other projects or programs on the Hanford Site would be sealed or closed and decommissioned. In some instances, only the lower portion of the drill hole would be sealed as either future monitoring or other uses may continue in the near-surface portion of the borehole. Borehole sealing will be done in accordance with applicable U.S. Environmental Protection Agency (EPA) groundwater protection standards to protect aquifer systems.

The finished boreholes vary in diameter from 76 to 273 mm (3.0 to 10.75 in.), and in depth from 46 m (150 ft) to nearly 1,400 m (4,600 ft). The holes are cased with steel, flush-jointed casing from the surface to appropriate testing levels.

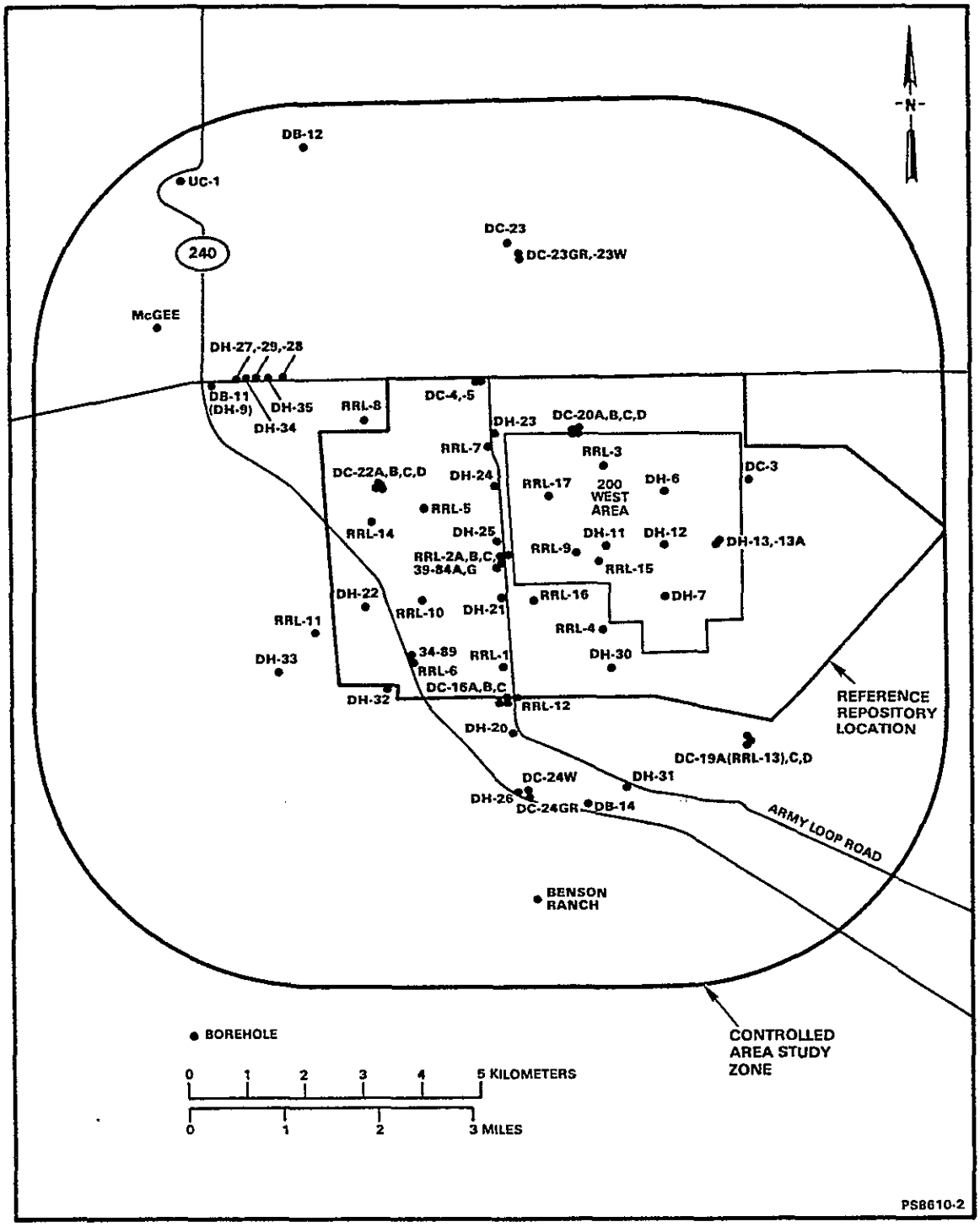

Figure 8.7-1. Location map for key Basalt Waste Isolation Project boreholes presently drilled in the controlled area study zone. Information for this location map was taken from borehole status charts and location maps.

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A cement plug will be placed in accordance with Washington State oil and gas well regulations (WAC, 1982) below each freshwater strata along with a cement plug at the surface. The fill between plugs will be an approved heavy drilling mud. The regulations require an uncased hole to be plugged between saline and freshwater zones. None of the aquifers evaluated in the controlled area study zone meet the definition of saline water (10,000 p/m solids). A steel plate shall then be welded to the top of the casing at the surface consistent with applicable regulatory requirements. Any cement plugs located above the drilling mud will be placed on top of a hole packer.

The surface area disturbed by the drilling activity will be returned as nearly as practicable to its original condition (DOE, 1985, Vol. I, Part II, Section 7.6).

After a complete review of borehole logs and histories, a plan for sealing each borehole will be prepared and will include the following steps (not necessarily in this sequence for every borehole):

1. Piezometer tubes, cables, and other instruments will be removed from the boreholes before any sealing activities begin. If these items were previously grouted in place, they will be removed by grinding, using a junk milling tool.

2. The downhole water chemistry will be analyzed for salt, chloride, fluoride, and other ion content to (a) determine where the water is no longer fresh or potable and (b) adjust the cement chemistry in the plugs to handle the various ion contents found at various levels in the boreholes.

3. The condition of the borehole may be confirmed by a downhole television camera survey or other well-logging techniques.

4. Whipstocks will be removed, and all holes whipstocked from a parent will be sealed.

5. Borehole casings that have not been grouted in place will be pulled from the hole before any sealing activities begin.

6. Seals or plugs then will be placed in locations where the rock conditions are most favorable. The sequence of grouting or sealing of the borehole starts at the bottom of the hole and extends by stages to the surface. Plugs, muds, and backfills will be placed at predetermined elevations by standard drilling techniques.

7. The portions of the boreholes in the Hanford and Ringold Formations may be filled with sand; it is not necessary to prevent vertical communication of water in these formations since they are unconfined aquifers and are largely sands and gravels.

8. A concrete cap at the top of the hole (below the steel plate) will be installed to prevent surface water from flowing down into the hole.

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Plans for determining alternative concepts and additional details of the borehole sealing program are found in Section 8.3.3.4. Borehole sealing concepts for the repository are found in Section 6.2.8.3.

Surface facilities required to support borehole drilling including equipment, structures, and concrete pads will be removed. The bermed drill cuttings pit will be backfilled and compacted with the berm material. Each drill site of approximately 4,047 m^2 (1 acre) will be graded as nearly as possible to the natural grade, and the disturbed surface will be planted with native vegetation. Permanent markers may be installed at each decommissioned borehole.

8.7.2.2 Subsurface borehole closure and decommissioning

In addition to the boreholes drilled from the surface, a large number (50 to 150) of boreholes in diameters ranging from 45.7 to 76.2 mm (1.8 to 3.0 in.) will be drilled from underground openings with penetrations ranging from approximately 3 to 300 m (10 to 1,000 ft) during site characterization. From the shafts, boreholes will be drilled through portholes in and above the shaft station area before excavation and then through other portholes at various depths to support testing and to verify shaft-liner grouting. Additional boreholes will be drilled from the drifts and test chambers to support testing, excavation advance, and other needs.

Boreholes drilled outward from the exploratory shafts will be plugged or sealed with compatible cement grout prior to, during, or at the conclusion of their useful service. This will be accomplished by standard high-pressure grouting techniques from the shafts. Those drill holes in the drifts, test chambers, and shaft station excavations not previously sealed as part of the testing program will not be sealed unless they have penetrated a water-bearing zone above or below the Cohassett flow, which contains the underground openings.

8.7.2.3 Shaft closure and decommissioning

The two shafts constructed to support the Exploratory Shaft Facility underground construction and test activities were described in Section 8.4.2.1.1. A vertical cross section of a shaft constructed by drilling techniques is shown in Figure 8.7-2. The innermost steel liner will extend the entire length of the shaft. The annular regions between liner and excavation wall and between successive liners in the upper portions of the shaft will be filled with grout except where chemical seal rings in the annular regions (described in Section 8.4.2.1.1) will be installed to prevent or reduce vertical interconnection between aquifers. There are shaft fixtures inside the shaft liner and utility pipes (compressed air and water lines) in the annular grouted region outside the liner. (See Fig. 8.4-10 for a cross-section showing the shaft fixtures.)

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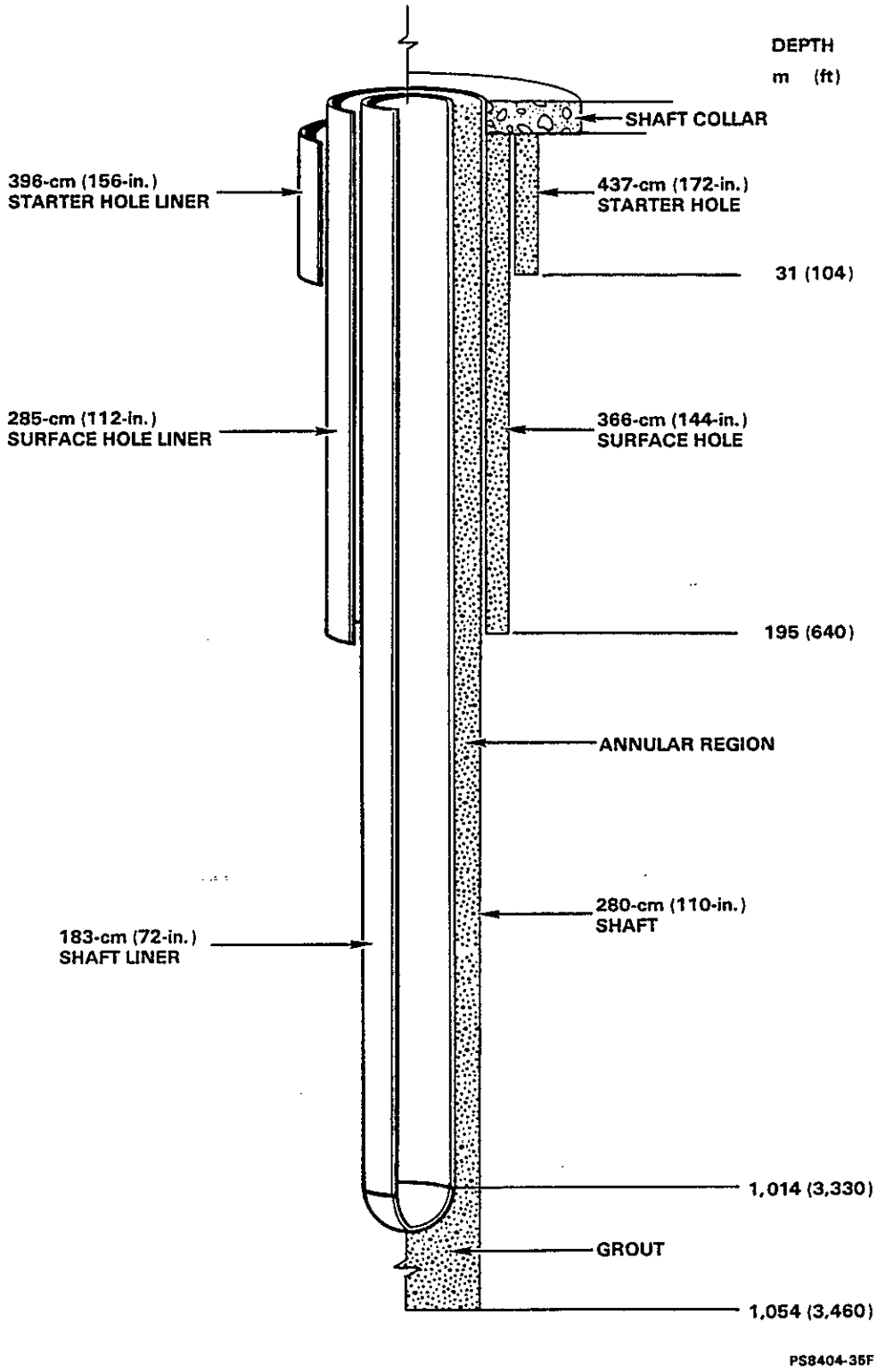

Figure 8.7-2. Drilled shaft concept.

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The first consideration in shaft seal design is the location of the aquifer seals. In an unlined shaft, the seals would be placed above and below any water-bearing zones. To provide assurance that interconnection of aquifers would not take place (even if a hole were to develop in the shaft lining at the aquifer location), the seals in the lined shaft are placed in the same location as they would have been in an unlined shaft. The geologic section and potential seal locations are shown in Figure 8.7-3. The major sedimentary interbeds of the Ellensburg Formation are identified. The seal locations also reflect interbeds too thin to show in the geologic section. The Ellensburg Formation is described in Section 1.2.1.3.1 of Chapter 1.

The final closure of the shafts will be accomplished in accordance with applicable EPA groundwater protection standards to protect aquifer systems. At this time, many concepts of shaft sealing have been proposed. The concepts presented here are preliminary and appear to fulfill the basic requirement to provide low permeability barriers to vertical groundwater flow. Shaft sealing concepts to slow radionuclide travel for the filled repository are found in Section 6.2.8.1.

Prior to shaft sealing, the water and compressed air lines that are embedded in the cemented annulus outside the shaft casing will be filled with grout. The interior of the shaft casings will be cleared of vertical pipelines or other utility lines and other shaft fixtures either before or concurrently with backfilling of the shaft.

The fundamental shaft sealing concept is to create vertical compartments within the lined shaft. These compartments are composed of seal materials or backfills. If the seals or backfills need to be restrained, bulkheads will be constructed.

Seals will typically be composed of two different seal materials to provide redundancy and thus ensure adequacy. These seals may be compacted bentonite, crushed basalt and bentonite, concretes, or seals of the same composition as the annulus chemical seal rings. Backfills between seals may be composed of sand, crushed basalt, graded crushed basalt mixed with sodium bentonite, or sand or crushed basalt with a small amount of cement.

Bulkheads, if required to prevent backfill or seal movement, would be tied into anchors on the inside of the shaft liner. They would be composed of concrete of either standard composition or a prepack of aggregate with cement slurry filling the voids.

Since the shaft stations must be backfilled as part of the shaft filling and sealing, a concrete bulkhead will be placed in the shaft stations or in the drift at the end of the station to create a holding dam.

After the backfill is placed into the shaft (now sealed) and the last major aquifer (Rattlesnake Ridge interbed) is confined, the remainder of the shaft may be filled with sand, crushed basalt, or graded crushed basalt with bentonite. Sand and crushed basalt could be emplaced as a slurry, while the graded crushed basalt could be dumped directly down the shaft. Slurry emplacement would require a pumping system to decant the excess water from the

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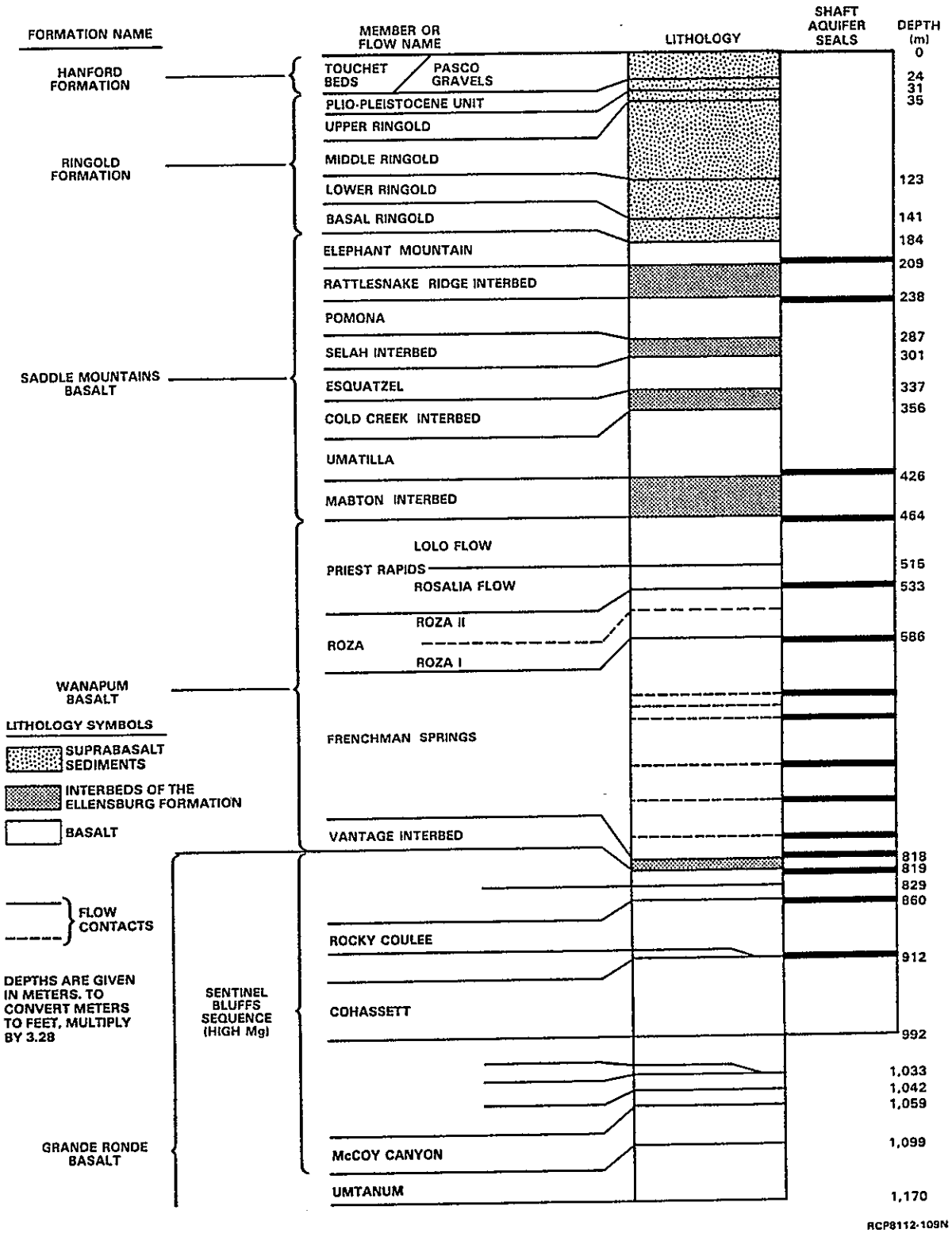

Figure 8.7-3. Conceptual location of aquifer seals in relation to the geologic section in the controlled area study zone. Depths are from borehole RRL-2.

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top of the fill material. Sand is less costly than crushed basalt and is a major constituent of these formations above the last aquifer.

The top of the shafts will be sealed by a cap created by cutting off the shaft liner 6 m (20 ft) down the shafts to the top of the shaft collar and removing this liner and the grout between it and the next outer liner (the surface hole liner). The resulting hole will then be filled with concrete to about 0.6 m (2 ft) below the planned final ground level. This concrete plug will be sitting on top of the shaft liner not inside the liner. This conceptual shaft cap is shown in Figure 8.7-4.

After the shafts have been sealed and the surface of the site has been restored, a marker explaining the history of the shafts may be emplaced.

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8.7.2.4 Closure and decommissioning of subsurface openings

The horizontal subsurface openings excavated out from the exploratory shafts for the exploratory shaft test program are described in Section 8.4.2.2. Ground support for these openings could vary from none at all to various combinations of rock bolts, wire mesh, shotcrete, and steel sets (with lagging) depending on the in situ rock conditions encountered.

Major structures and equipment, including test equipment, dewatering pumps, and materials handling equipment, will be removed from shaft stations, all underground drifts, and test chambers during closure operations.

Test chambers, drifts, and shaft stations 3 m (10 ft) high or with potential over-excavation up to 4 m (13 ft) high will be located in the dense interior of the Cohassett flow. When caving occurs in this relatively homogenous rock, the roof rock falls into the drift breaking into pieces. With a minimum of rotation the increase in volume or bulking of this rock is about 50%. If caving occurs across the full width of the back or roof of the drift, it should continue upward until a height of approximately three times the original height of the drift is reached. Bulking of the broken rock would then fill the original opening plus the caved opening. Kaiser Engineers, Inc./Parsons Brinckerhoff Quade & Douglas, Inc. (KE/PB), in Section 5.1.1 of the Site Characterization Plan Conceptual Design Report (KE/PB, 1987), provided an ultraconservative estimate of the extent of caving as six to seven times the height of the drift. This is only credible if a fault striking parallel to the drift occurs on one side of the drift and the dip of the fault is such that it restricts the width of the caved volume. Even with the KE/PB estimate, the overlying water-bearing formation would not be reached. If some very unusual condition in the Exploratory Shaft Facility is found that indicates this caving potential must be minimized, this can be accomplished by filling the underground openings with hydraulic sand fill from the surface or by other backfilling techniques. Hydraulic sand fill is essentially crushed rock of sand-size particles and smaller carried in water delivered by pipeline as a relatively high-density slurry of 55% to 63% solids. A pipeline in one of the shafts would deliver the slurry to the area to be filled. Excess water from the slurry would be pumped back to the surface.

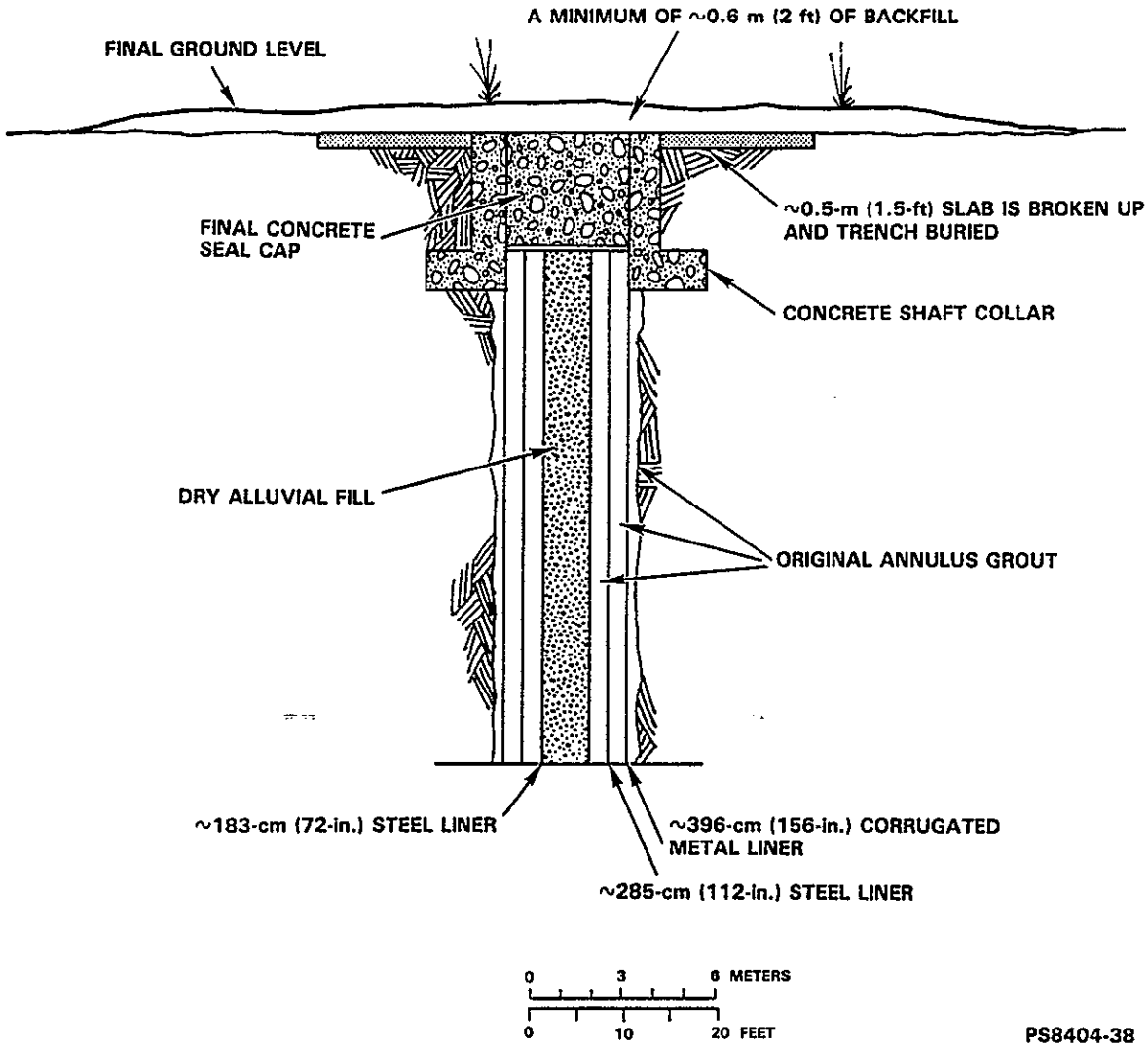

Figure 8.7-4. Conceptual shaft cap.

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Hydraulic sand fill is an effective backfill used in mining to minimize rock movement around large underground openings. The sand fill does not shrink or expand when emplaced. However, any subsequent rock movement around the filled area would compress the sand fill. Greater compressive strength can be obtained from the sand fill by the addition of cement to the slurry.

Hydraulic filling of the exploratory shaft underground openings is illustrated in Figure 8.7-5. The sand pile in the figure would probably be created by crushing the basalt taken from the underground excavation. Backfilling concepts for the repository were discussed in Section 6.2.7.

8.7.2.5 Surface facility decommissioning

Site structures include buildings, concrete foundations, shaft headframes, and the cooling tower. The prefabricated metal buildings protecting the switchgear and the main and standby hoists are on concrete foundations. Other concrete foundations on the site include those beneath the shaft headframes and the cooling tower.

For each of the exploratory shaft surface facilities, the major pieces of equipment are the main hoist, standby hoist, shaft conveyance, standby generator, compressors, shaft ventilation equipment, and electrical distribution equipment.

The conceptual decommissioning plan for those onsite surface facilities not identified for future use includes the following activities:

- Buildings will be emptied of their contents, disassembled, trucked off the site, and salvaged.
- Equipment (e.g., items required for hoisting, mine ventilation, pumps, electrical generators, and storage tanks) will be removed from the site and salvaged.
- The hoist and headframe footings and other foundations standing above the ground surface will be cut below the surface level or broken into manageable pieces, loaded onto trucks, and moved to acceptable disposal sites. These foundation areas will be backfilled and graded smooth. Subsurface concrete foundations will be left in place and, where appropriate, covered with fill material.
- All fences will be removed.

All salvaging activities will be done in accordance with the Nuclear Waste Fund requirements of the Nuclear Waste Policy Act of 1982 (NWPA, 1983).

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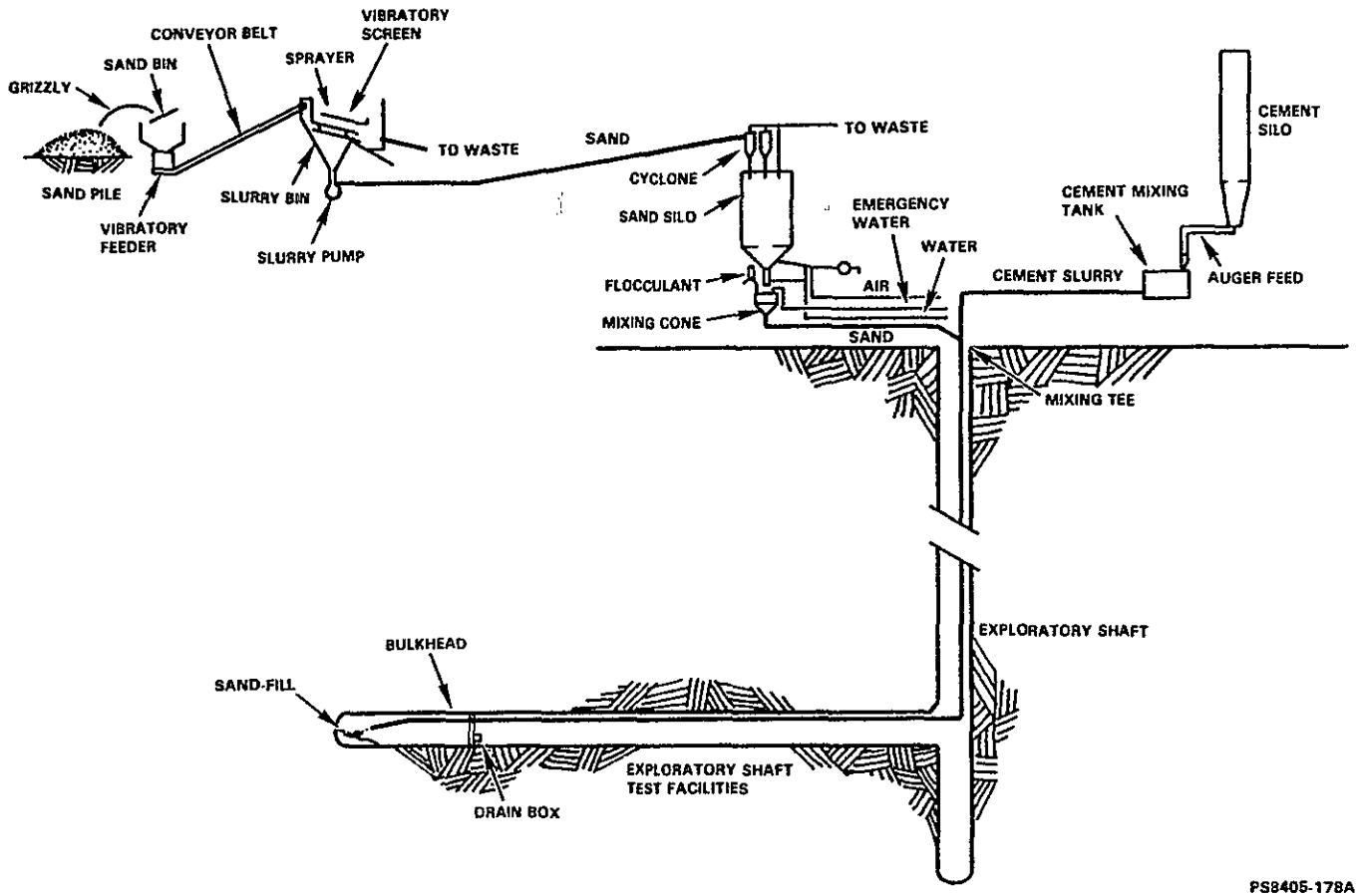

Figure 8.7-5. Diagram of hydraulic sand filling in the exploratory shaft.

CONSULTATION DRAFT

8.7.2.6 Earthworks, surface emplacements, and utilities

Principal earthworks on the Exploratory Shaft Facility site are roads, mud pits, mine water discharge pond, basalt storage pile, a safety berm for the explosives storage magazine, and a retention pond for storage of Exploratory Shaft Facility underground inflow water. Emplacements include diesel fuel storage and septic tanks and intrasite utilities distribution equipment. The buried diesel fuel storage tank has a capacity of 18,927 L (5,000 gal), and septic tanks are in the capacity range of several thousand gallons. Intrasite utilities include water, sanitary sewage, and communications and electric power lines.

The present concepts for decommissioning these earthworks, surface emplacements, and utilities are explained in the following list of specific actions:

- Any asphaltic road or parking lot surfaces will be broken up and stockpiled for future use as subbase in major road building projects. Road subbases and unsurfaced roads will be scarified and graded to near-natural ground contours, density, and permeability. Since major road cuts and fills are not expected, there will be minimal need to smooth the contours.

- Drilling mud will be disposed of in accordance with applicable regulations.

- The mud pit baffles will be removed and the pit will be filled and compacted with rock and soil materials using material from the basalt storage pile and the explosive magazine berm.

- Any liner and (or) sludge in the mine water discharge pond will be removed to existing landfill sites, and the pond will be filled with berm and other material.

- The remaining portion of the basalt storage pile will have its contours smoothed by grading. The basalt may be used as aggregate for future Hanford Site construction.

- Power and water distribution to the Exploratory Shaft Facility site will be disconnected near the site boundary. The water and power lines extending from the site boundary to the sources will be left in place for possible future use.

- The power lines and poles will be removed from the site back to the east side of Army Loop Road (see Fig. 8.4-1).

- The water line will be drained, cut at the Exploratory Shaft Facility site boundary, and capped underground.

- Water and sewer pipes and electrical conduits extending above ground will be cut off at below-grade main connections.

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- Septic tanks and similar facilities will be filled with dirt and abandoned in place.
- Fuel storage tanks will be dug out and removed from the site, and the disturbed area will be backfilled.

Other decommissioning concepts will be evaluated during advanced conceptual design.

8.7.3 PLANS FOR MITIGATION OF ANY POTENTIALLY SIGNIFICANT ADVERSE ENVIRONMENTAL IMPACTS CAUSED BY SITE CHARACTERIZATION ACTIVITIES

The Nuclear Waste Policy Act of 1982 (NWPA, 1983, Section 113(b)) requires that the site characterization plan include plans (e.g., the Environmental Monitoring and Mitigation Plan) for mitigating significant adverse environmental impacts caused by site characterization activities at a candidate site determined unsuitable as a repository. As previously mentioned, specific plans for mitigation of any significant adverse environmental impact will be developed in consultation with the state and Indian tribes if such a determination of unsuitability is made.

8.7.4 REFERENCES

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NWPA, 1983. Nuclear Waste Policy Act of 1982, Public Law 97-425, 96 Stat. 2201, 42 USC 10101. [MF 4639]

RKE/PB, 1984. Exploratory Shaft Phase I Title II Design Report System Design Description, SD-BWI-DR-001, Rev. 2, Vols. 1 and 2, Raymond Kaiser Engineers, Inc./Parsons Brinckerhoff Quade & Douglas for Rockwell Hanford Operations, Richland, Washington. [MF 0891]

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SITE CHARACTERIZATION PLAN

Glossary

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1.0 INTRODUCTION

1.1 REFERENCES AND USE OF THE GLOSSARY

The definitions in this glossary come from multiple sources and apply to multiple technical fields. Where applicable, the reference sources (reference Section 4.0) are shown in parentheses after the definition. Commonly used abbreviations are given in Table 1. Some of the definitions used in this glossary are site specific and therefore may differ somewhat from the definitions in other Site Characterization Plans.

Table 1. Source keys

Use key	Source
BWIP	Terms derived from the Basalt Waste Isolation Project (BWIP)
DOE-RL	Terms used by the U.S. Department of Energy-Richland Operations Office
EA	Terms taken from the Environmental Assessment (DOE 1986)
IRM	Terms used by the BWIP Information Resource Management Department
MP	Terms taken from the Mission Plan (DOE 1985)
NWPA	Terms taken from the Nuclear Waste Policy Act of 1982
QA	Terms used by the BWIP Quality Assurance Department
QA1	Terms taken from ANSI/ASME (1983)
QA2	BWIP terms established specifically for use in quality assurance policies and procedures
QA3	Terms taken from ANSI (1983)
USBM	Terms taken from USBM (1968)

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2.0 ABBREVIATIONS AND ACRONYMS

The abbreviations section is included for reference as an aid to the user. New abbreviations are coined daily.

AA	atomic absorption (spectroscopy)
ACD	advanced conceptual design
ACLIN	astronomical climate index
ACRS	Advisory Commitee on Reactor Safeguards (U.S. Nuclear Regulatory Commission)
ADPE	automated data processing equipment
ADP	automated data processing
A/E	architect/engineer
AEGIS	assessment of effectiveness of geologic isolation systems program
AFR	away from reactor (storage facility)
AGCM	atmospheric general circulation model
ALAP	as low as practicable
ALARA	as low as reasonably achievable
AMC	Assistant Manager, Commercial Nuclear Waste
ANSI	American National Standards Institute
AQCR	air quality control region (U.S. Environmental Protection Agency)
ASCE	American Society of Civil Engineers
ASCII	American Standard Code for Information Interchange
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
ba	below (the Mazama) ash
BLM	Bureau of Land Management, U.S. Department of the Interior
BOP	basalt operating procedure
BP	before present
BPA	Bonneville Power Administration
BQARD	Basalt Quality Assurance Requirements Document (DOE-RL 1986)
BRCP	BWIP Regulatory Compliance Program
BRIIP	BWIP Regulatory and Institutional Integration Plan
BRIRD	BWIP Regulatory and Institutional Requirements Document
BRMC	Basalt Records Management Center
BWI	Basalt Waste Isolation (Division, DOE-RL)
BWIP	Basalt Waste Isolation Project
BWIPO	Basalt Waste Isolation Project Office (obsolete)
BWR	boiling water reactor
CAD	computer-aided design
CADD	computer-aided design and drafting
CAE	computer-aided engineering
CAM	computer-aided manufacturing
CASZ	controlled area study zone
CDR	conceptual design report
CENRTC	capital equipment not related to construction

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CEP	capital equipment projects
CFR	Code of Federal Regulations
CH	contact handled
CHLW	commercial high-level waste
CLIMAP	climate long-range mapping project
COHMAP	Cooperative Holocene Mapping Project
CRWMP	Civilian Radioactive Waste Management Program
D&D	decontamination and decommissioning
DBA	design basis accident
DBE	design basis earthquake
DBF	design basis fire
DBMS	data base management system
DBTW	design basis tornado and windstorm
DBX	design basis explosion
DCN	data communication network
DCS	document control system
DEIS	draft environmental impact statement
DHLW	defense high-level waste
DOD	U.S. Department of Defense
DOE	U.S. Department of Energy
DOE-HQ	U.S. Department of Energy-Headquarters
DOE-RL	U.S. Department of Energy-Richland Operations Office
DOT	U.S. Department of Transportation
DRB	design review board
EA	Environmental Assessment
EAC	estimate-at-completion
EAR	Environmental Assessment report
EBM	energy balance model
EE	(a) electrical engineer (or electrical engineering) (b) environmental evaluation
EIS	Environmental Impact Statement
EMMP	Environmental Monitoring and Mitigation Plan
EPA	U.S. Environmental Protection Agency
EPRI	Electric Power Research Institute
ER	environmental report
ERDA	U.S. Energy Research and Development Administration (now DOE)
ES	exploratory shaft
ESF	Exploratory Shaft Facility
FCC	Federal Communications Commission
FDC	functional design criteria
FEIS	final environmental impact statement
FMEA	failure mode and effects analysis
FR	Federal Register
FSAR	final safety analysis report
FTS	Federal Telecommunications System

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GAO	General Accounting Office
GCM	general circulation model
GCR	geologic characterization report
GEIS	generic environmental impact statement
GFDL	geophysical fluid dynamics laboratory
GISS	Goddard Institute for Space Sciences
GOCO	government owned, contractor operated
GRD	generic requirements document
GSA	General Services Administration
GWTT	groundwater travel time
HEDL	Hanford Engineering Development Laboratory
HEHF	Hanford Environmental Health Foundation
HEPA	high efficiency particulate air (filter)
HLLW	high-level liquid waste
HLSW	high-level solidified waste
HLW	high-level waste
HPS	Hanford plant standards
HVAC	heating, ventilating, and air conditioning
IAEA	International Atomic Energy Agency
IC	integrating contractor
ICC	Interstate Commerce Commission
IEEE	Institute of Electrical and Electronics Engineers
INEL	Idaho National Engineering Laboratory
KE/PB	Kaiser Engineers, Inc./Parsons Brinckerhoff Quade & Douglas, Inc. (formerly RKE/PB)
LA	license application
LCC	life cycle cost
LCCA	life cycle cost analyses
LCCM	life cycle cost model
LLW	low-level (radioactive) waste
LOE	level of effort
LWR	light water reactor
Ma	million years ago
MGDS	mined geologic disposal system
M-K	Morrison-Knudsen Company, Inc.
MORT	management oversight and risk tree
MPC	maximum permissible concentration
MRS	monitored retrievable storage
MSA	major system acquisition
MSHA	Mine Safety and Health Administration
MSL	mean sea level
MTHM	metric tons of heavy metal
MTU	metric tons of uranium

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NBS	National Bureau of Standards
NCAR	National Center for Atmospheric Research
NDA	nondestructive analysis
NDE	nondestructive examination
NDT	nondestructive testing
NEC	National Electrical Code
NEPA	National Environmental Policy Act of 1969
NFC	National Fire Code
NFPA	National Fire Protection Association
NIOSH	National Institute for Occupational Safety and Health
NNWSI	Nevada Nuclear Waste Storage Investigations
NOAA	National Oceanic and Atmospheric Administration
NRC	U.S. Nuclear Regulatory Commission
NSTF	Near-Surface Test Facility
NTS	Nevada Test Site
NWPA	Nuclear Waste Policy Act of 1982
NWRB	nuclear waste repository in basalt
NWS	National Weather Service
OCRWM	Office of Civilian Radioactive Waste Management
OGR	Office of Geologic Repositories
OMB	Office of Management and Budget
OPC	official point of contact
ORNL	Oak Ridge National Laboratory, Oak Ridge, Tennessee
OSHA	Occupational Safety and Health Administration
OSTS	Office of Storage and Transportation Systems
PA	performance assessment
PACE	plant and capital equipment
PE&D	Plant Engineering and Design (DOE-RL 5700.2A)
PL	public law
PMP	Project Management Plan (DOE-RL 1987a)
PNL	Pacific Northwest Laboratory
PP	Project Plan (DOE-RL 1987b)
ppt	precipitation
PSAR	Preliminary Safety Analysis Report
PSS	physical subsystem structure
PSWBS	project summary work breakdown structure
PWR	pressurized water reactor
QA	Quality Assurance
QAPP	Quality Assurance Program Procedure
QC	Quality Control
RAM	(a) reliability, availability, and maintainability (b) radiation air monitor
R&D	research and development
RH	remote handled
RHO	Rockwell Hanford Operations

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RKE/PB	Raymond Kaiser Engineers/Parsons Brinckerhoff Quade & Douglas, Inc. (obsolete) See KE/PB.
RL	Richland Operations Office of the DOE or the site administered by that office
RRL	reference repository location (used throughout the BWIP; however, CASZ and RIZ where applicable are preferred)
RW	radioactive waste
SAD	safety assessment document
SAR	safety analysis report
SCP	site characterization plan
SCR	site characterization report
SDD	subsystem design description
SEMP	System Engineering Management Plan
SF	spent fuel
SMMP	Socioeconomic Monitoring and Mitigation Plan
SOW	statement of work
SPECMAP	spectral mapping project
SSD	subsystem description
SSDR	subsystem design requirements
SST	sea surface temperature
TRU	transuranic
TVA	Tennessee Valley Authority
UBC	Uniform Building Code (UBC 1986)
UL	Underwriters' Laboratories, Inc.
USBM	U.S. Bureau of Mines
USC	U.S. Code (of laws)
U.S. DOE	U.S. Department of Energy. See also DOE.
USGS	U.S. Geological Survey
WBS	work breakdown structure
WDOE	Washington State Department of Ecology
WESF	Waste Encapsulation Storage Facility
WHC	Westinghouse Hanford Company
WHIF	Waste Handling and Isolation Facility
WIPP	Waste Isolation Pilot Plant
WP	waste package
WPPSS	Washington Public Power Supply System
WVHLW	West Valley High-Level Waste

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3.0 TERMS

The definitions that follow represent the accepted usage for the Basalt Waste Isolation Project.

abnormal occurrences Those occurrences stemming from malfunctions of systems, operating conditions, or resulting from operator error that would not have a significant effect beyond the exclusion area. (EA)

absorbed radiation dose A measure of the amount of ionizing radiation deposited per unit mass of absorbing medium. The unit of absorbed radiation is the rad. (EA)

accelerated testing Testing conducted under conditions designed to increase the rate of change of selected parameters so the observed performance during the test period is used to simulate normal performance after a much longer time period. (BWIP)

accessible environment Includes (1) the atmosphere; (2) land surfaces; (3) surface waters; (4) oceans; and (5) all of the lithosphere that is beyond the controlled area. (40 CFR 191.12)

accident An unscheduled event initiated by equipment or component failure, operator error, or a disruptive event (e.g., faulting, volcanism). (BWIP)

accident, credible An event that could impose extreme conditions. In a specific application for the waste package, may be called "credible event" or "disruptive event" after waste emplacement. (BWIP)

accident, design basis An event that defines the upper limit of credible accidents (conditions). (BWIP)

accountability (as related to the nuclear industry) The capability to determine the material balance in the inventory of source and fissionable elements and isotopes, accounting for all significant amounts of incoming and outgoing materials. (EA)

accuracy The degree to which a measure conforms to a recognized standard or true value. Accuracy is determined both by the degree of systematic error of measurement (bias) and by precision. (BWIP)

Act The Nuclear Waste Policy Act of 1982. (EA)

actinide (series) The group of elements with atomic numbers 89 through 103. (McGraw-Hill 1984)

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activation The process of making a material radioactive by bombardment with neutrons, protons, or other nuclear particles in a radiation generating system. (BWIP)

active corrosion mode A mode expected to occur under expected repository conditions for a given container material.

active fault A fault along which there is recurrent movement, which is usually indicated by small, periodic displacements or seismic activity. (10 CFR 960.2)

activity

(a) (as related to nuclear chemistry) A measure of the rate at which a material is emitting nuclear radiations (usually given in terms of the number of nuclear disintegrations per unit of time (Bq) or the curie (Ci). (BWIP)

(b) (as related to thermodynamics) A thermodynamic measure of concentration.

(c) (as applied in Section 8.3 of the SCP) Refers to a specific action or group of actions in support of an investigation. An activity occurs at the same hierarchical level as a study but is not governed by a separate study plan. It may consist of design, modeling, or data-compilation actions.

adit A nearly horizontal passage from the surface by which a mine is entered. (An adit is open to daylight at one end.) See tunnel. (EA)

adsorption Surface retention of atoms, molecules, or ions by a solid or a liquid. (EA)

advanced conceptual design The design that presents the selected design alternatives and refines and fixes the design criteria and concepts to be made final in later design efforts. This design forms the basis for the demonstration of project feasibility and estimation of life cycle costs. Preliminary drawings are prepared and a construction schedule is developed as required by DOE 6410.1.

aeromagnetic survey A survey of the Earth's magnetic field using an airborne magnetometer. (BWIP, EA)

affected area The area of socioeconomic or the area of environmental impact, each of which will vary in size among potential repository sites. (10 CFR 960.2)

affected Indian Tribe Any Indian Tribe (1) within whose reservation boundaries a repository for radioactive waste is proposed to be located or (2) whose Federally defined possessory or usage rights to other lands outside the reservation's boundaries arising out of congressionally ratified treaties may be substantially and adversely affected by the locating of such a facility: Provided that the Secretary of the Interior finds, upon the petition of the appropriate governmental officials of the tribe, that such effects are both substantial and adverse to the tribe. (10 CFR 960.2)

affected State Any State that (1) has been notified by the U.S. Department of Energy in accordance with Section 116(a) of the Nuclear Waste Policy Act as containing a potentially acceptable site; (2) contains a candidate site for site characterization or repository development; or (3) contains a site selected for repository development. (10 CFR 960.2)

aggradation The building up of the Earth's surface by the deposition of sediment. (EA)

aging Storage of radioactive materials, especially spent nuclear fuel, to permit the decay of short-lived radionuclides. (EA)

agreement State Any State with which the U.S. Nuclear Regulatory Commission has entered into an effective agreement under Subsection 274b of the Atomic Energy Act of 1954, as amended.

airborne Supported by air. Airborne contamination applies to radioactive material suspended in the air. (EA)

air change The rate of change of ventilation air, usually in terms of air changes per hour. (EA)

air lock (ventilation) A compartment between areas of different internal pressures and equipped with doors or hatches so as to allow passage between the areas without varying the pressure difference or allowing a free exchange of atmospheres between the areas. (BWIP)

air monitor

(a) Air sampler with electronic circuitry for the continuous detection of radioactivity, to warn personnel of changes in airborne radioactivity. (EA)

(b) Sensors and alarms for detection of hazardous gases such as methane.

air sample A sample of air for determining the amount of radioactive material present.

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albedo The ratio of the amount of electromagnetic energy reflected by a surface to the amount of energy incident upon it.

algorithm A set of well-defined rules for the solution of a problem in a finite number of steps. (McGraw-Hill 1984)

alkaline Containing sodium and (or) potassium in excess of the amount needed to form feldspar with the available silica. In chemistry: a substance with a pH greater than 7. (EA)

alluvial fan Sloping, fan-shaped mass of loose sedimentary material deposited by a stream at the place where it emerges from an upland region into a broad valley or plain. (BWIP)

alluvial plain A level or gently sloping surface adjacent to a stream, developed over time by the periodic flooding of and associated deposition by the stream (either existing today or active in the past). (EA)

alluvium Clay, silt, sand, gravel, or similar material that is not compacted and has been deposited in fairly recent geologic time by streams, rivers, or floods. (EA, MP)

alpha decay A radioactive transformation in which an alpha particle is emitted by a nuclide, thus changing the nuclide to another one with a smaller atomic number and weight. (EA)

alpha particle A positively charged particle emitted in the radioactive decay of certain nuclides. Made up of two protons and two neutrons bound together, it is identical with the nucleus of a helium atom. It is the least penetrating of the three common types of radiation (i.e., alpha, beta, and gamma). (EA)

alpha radiation The emission of alpha particles (helium nuclei) from a material undergoing nuclear transformation by alpha decay. (BWIP)

alpha waste Synonymous with transuranic waste.

altithermal A term for a dry postglacial interval (from about 7,500 to 4,000 yr ago) following the Anathermal and preceding the Medithermal, during which temperatures were warmer than at present. It corresponds to the Atlantic interval or the middle part of the Hypsithermal.

analytical tools The numerical or conceptual models employed as part of the licensing strategy (e.g., models of physical processes) or, more generally, the processes by which quantitative or qualitative estimates are obtained from input data of any kind.

anion A negatively charged ion.

anisotropic Exhibiting properties with different values when measured along different axes. (MP)

anode The electrode of an electrolytic cell at which oxidation occurs.

anoxic A general term meaning in the absence of oxygen, usually implying reducing conditions. (EA)

anticipated processes and events Those natural processes and events that are reasonably likely to occur during the period the intended performance objective must be achieved. To the extent reasonable in the light of the geologic record, it shall be assumed that those processes operating in the geologic setting during the Quaternary Period continue to operate but with the perturbations caused by the presence of emplaced radioactive waste superimposed thereon. (10 CFR 60.2)

anticline An up-arched fold in rocks composed of strata that dip outward from a common ridge or axis. The core of an anticline contains stratigraphically older rocks and is convex upward. Antonym: syncline. (EA)

anticlinorium A series of anticlines and synclines so arranged structurally that together they form a general arch or anticline. (EA)

antithetic fault A fault that dips in the opposite direction from the direction in which the associated sediments dip. Opposite of synthetic fault. (EA)

aphanitic Describing the texture of rocks whose mineral constituents are so fine that the individual crystals or grains cannot be distinguished by the unaided eye. (BWIP, EA)

application The act of making a finding of compliance or noncompliance with the qualifying or disqualifying conditions specified in the guidelines (10 CFR 960) of Subparts C and D, in accordance with the types of findings specified in Appendix III. (10 CFR 960.2)

applied research Systematic study directed toward fuller scientific knowledge for direct use in fulfilling specific requirements. (DOE 4700)

aquiclude

(a) A geologic formation that will not transmit water fast enough to furnish an appreciable supply. (EA)

(b) A hydrogeologic unit that has a distinctively low permeability by comparison with adjacent aquifers and can serve to maintain artesian pressures in such aquifers. (Supplants the terms aquitard and aquifuge.)

aquifer A formation, a group of formations, or a part of a formation that contains sufficient saturated permeable material to yield significant quantities of water to wells and springs. (10 CFR 960.2)

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aquifer system A heterogeneous body of intercalated permeable and less permeable material that acts as a water-yielding hydraulic unit of regional extent. (BWIP)

aquifuge An impermeable body of rock; a rock with no interconnected openings and thus lacking the ability to absorb and transmit water. See aquiclude, aquitard, confining unit. (BWIP)

aquitard A confining bed that retards but does not prevent the flow of water to or from an adjacent aquifer; a leaky confining bed. It does not readily yield water to wells or springs, but may serve as a storage unit for groundwater. See aquifuge, aquiclude, confining unit. (EA, MP)

architect/engineer (A/E) The offsite design agency contracted to the U.S. Department of Energy-Richland Operations Office to provide design services on the Basalt Waste Isolation Project. (QA)

area The geographic extent of the Pasco Basin. See areal extent. (BWIP)

areal extent The size of an area of interest. Table A-1 (appendix) shows the areal extents of the candidate area, the site, and the surface and underground facilities of the repository.

argillaceous Applied to all rocks or substances composed of clay minerals or having a notable proportion of clay in their composition (e.g., shale, slate). (EA, MP)

argillite A compact rock, derived from either mudstone or shale, that has undergone a somewhat higher degree of induration than is present in mudstone or shale. (EA)

artesian Refers to water confined underground under pressure so that it will rise in a well. Thus, an artesian water body is one that is confined under hydraulic pressure since its hydraulic head rises above the top of the aquifer unit. (BWIP)

artesian wells Wells tapping groundwater confined under hydrostatic pressure. The water level in an artesian well is above the top of the artesian water body it taps. If the water level in an artesian well stands above the land surface, the well is a flowing artesian well.

as-built Describes a drawing or specification that incorporates all approved changes and is the final accepted configuration of a project, system component, or item.

assessment (as related to project management) A determination of project or system acquisition condition based on a review of project cost, schedule, technical status, and performance in relation to program objectives, approved requirements, and baseline project plans. (DOE 4700)

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atomic energy defense activity (or program) Any activity of the Secretary of Energy performed in whole or in part in carrying out any of the following functions: naval reactors development; weapons activities including defense inertial confinement fusion; verification and control technology; defense nuclear materials production; defense nuclear waste and materials byproducts management; defense nuclear materials security and safeguards and security investigations; and defense research and development. (EA, MP)

atomic mass The mass of a neutral atom of a nuclide. Usually expressed in the physical scale of atomic masses based on a unit equal to one-twelfth the mass of a carbon atom of mass 12.

attribute An inherent characteristic of the article to be inspected.

augite A common mineral of the clinopyroxene group. It is usually black, greenish black, or dark green and occurs as an essential constituent in many basic igneous rocks and in certain metamorphic rocks. (EA)

available thickness The portion of the Cohassett flow that would be used for repository excavation. The value adopted (47.7 m (156 ft)) is the mean flow thickness in the vicinity of the reference repository location (71.7 m 235 ft)), less the preclosure foundation buffer zone (9 m (30 ft)) at the base of the dense interior and the postclosure buffer zone (15 m (49 ft)).

availability The probability that a plant or information system, or some portion of an information system, will be usable when needed. It is typically computed by combining the reliability of the system components and analyzing component interdependences. (IRM)

back end of the fuel cycle Includes spent fuel transportation and storage, fuel reprocessing (may also include preparation of plutonium oxide fuel fabrication), and waste management. (EA)

backfill (as related to a repository) The placement of materials, originally removed or in combination with new materials, into the excavated areas of a mine, drifts, access ways, and shafts. (EA)

background radiation Radiation that is produced by sources such as naturally occurring radioactive minerals in the earth, cosmic rays, and naturally occurring radionuclides in living organisms. (EA)

barrier Any material or structure that prevents or substantially delays the movement of water or radionuclides. (10 CFR 960.2)

barrier, natural See natural barrier.

basal colonnade A subdivision of the flow interior of a basalt flow consisting of relatively well-formed columns typically with fewer primary fractures than in the entablature. (MP)

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basalt A dark- to medium-dark-colored mafic (iron-magnesium rich) extrusive igneous rock with small grains composed primarily of feldspar (calcic plagioclase), pyroxene, with or without olivine, and varying proportions of glass. (EA)

basalt flow The rock that is formed from molten basalt flowing onto the surface of the ground and solidifying in place. It includes the flow top, entablature, columnar-entablature, colonnade, pillow zones, and lower contact zones. (EA)

basalt interbed Sedimentary unit occurring between or alternating with sequential basalt flows. (BWIP)

Basalt Records Management Center The administrative entity within Engineering Management Systems responsible for the overall management, coordination, and control of records after submittal for retention processing. (QA)

Basalt Waste Isolation Project (BWIP) The U.S. Department of Energy project to design, construct, and operate a geologic repository for the storage of radioactive waste, including spent fuel, in basalt formations beneath and within the Hanford Site. (BWIP)

base case The effort and scope as presently planned. In environmental impact considerations and cost/benefit analyses, it is the detailed plan of actions from which impacts are assessed and to which reasonable alternatives will be compared. (BWIP)

base level (erosion) The theoretical limit or lowest level toward which the erosion of the Earth's surface constantly progresses; the level below which a stream cannot erode its bed. The general base level for the land surface is sea level. (BWIP)

baseline (as related to hydrology) The representative assemblage of pressure or hydraulic head measurements on which subsequent comparisons, analyses, and (or) decisions are based.

baselining Formally establishing and controlling program documents that contain task and subtask criteria, requirements, objectives, schedule, cost, and definition of deliverables. (BWIP)

basement rock A complex of undifferentiated rocks underlying the oldest identifiable rocks in the area. Precambrian rock. (BWIP)

basic research (as used in waste isolation) Systematic, fundamental study directed toward fuller scientific knowledge or understanding of subjects bearing on national energy needs. NOTE: The phrase "bearing on national energy needs" as used in the context of waste isolation does not exclude other basic research missions related to weapons or isotope production. (DOE 4700)

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basin A depressed area in the Earth's surface with no outlet. Sediments may have accumulated in such areas. (BWIP)

bedded salt Consolidated layered salt separated from other layers by distinguishable planes of separation such as by layers of argillaceous sediments. (BWIP)

bedding The arrangement of rock in layers, strata, or beds. (EA)

bedrock Solid rock that underlies all soil, sand, clay, gravel, and loose material on the Earth's surface. (EA)

benchmark A permanently fixed point of known elevation used as a reference for elevations. A primary benchmark is one close to a tide station to which the tide staff and tidal datum originally are referred.

benchmark code A computer code used for purposes of benchmarking.

benchmarking Computer code comparisons in which results obtained with a code are compared to those obtained with other available codes. The test cases used for benchmarking use data representative of the ranges expected in an actual repository setting and models representative of the processes expected. Benchmarking is complete when a reasonable consensus between independent code predictions is achieved. (BWIP)

bench scale (as related to testing) A type of laboratory (or occasionally field) test; refers to the size of tests being performed. Bench-scale tests are run to determine the practicability of incorporating an observed phenomenon into a design or test procedure. (EA)

bentonite Calcium or sodium montmorillonite clay or a mixture of both with variable magnesium and iron content formed by the alteration of volcanic ash. Bentonite, principally sodium montmorillonite, has the ability to absorb large quantities of water and to expand to several times its normal (dry) volume. (EA)

beta decay Radioactive change by the emission of beta particles. (EA)

beta particle A negatively charged particle, physically identical with the electron, that is emitted by certain radionuclides. (EA)

beta radiation Essentially high-energy electrons emitted from the nucleus of atoms undergoing nuclear transformation. (BWIP)

biosphere The part of the Earth in which life can exist, including the lithosphere (including soil), the hydrosphere, and the atmosphere. See also accessible environment. (MP)

biosphere transport (biotransport) Movement of radionuclides through food chains. Used in contrast to geotransport. (EA)

biostratigraphy Stratigraphy based on the paleontologic characteristics of rocks or stratigraphy by paleontologic methods; specifically, the separation and differentation of rock units on the basis of the description and study of the fossils they contain.

blasting
(a) The operation of breaking or dislodging rock by explosive charge.

(b) Abrasion affected by the movement of fine particles against a stationary fragment. In a sandblast or dry blasting the carrying agent is air; in wet blasting it is a current of water. (BWIP)

blind-hole drilling A technique for sinking shafts. It uses a multiple-cone bit with a diameter larger than 1.8 m (6 ft). (EA)

block faulting A type of vertical faulting in which the crust is divided into structural or fault blocks of different elevations and orientations. (EA)

boiling waste High-level liquid radioactive waste containing radionuclides (principally ^{90}Sr and ^{137}Cs) that provide sufficient decay heat to boil the liquid. Such liquid usually requires aging and some supplemental means of cooling. (BWIP)

boiling water reactor (BWR) A nuclear reactor that uses boiling water to generate electricity. (EA)

borehole An excavation, formed by drilling, that is essentially cylindrical and is used for exploratory purposes. (EA)

borehole jacking test A test measuring in situ rock-mass deformation through the application of unidirectional pressures to opposite sides of a borehole wall. (EA)

borehole log A record of the characteristics and thickness of the different layers of rock or other material encountered in the excavation of a borehole. (EA)

borosilicate glass A silicate glass containing at least 5% boric acid. It is used to solidify commercial or defense high-level waste. (EA)

breccia Rock consisting of sharp fragments cemented together or embedded in a fine-grained matrix. (EA)

buffer A solution whose pH is not very sensitive to the addition of small quantities of either strong acid or base.

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buffer zone (as related to a repository site) A designed and controlled portion of the site that surrounds the repository facility and is composed of essentially undisturbed geologic and surficial environment. See control zone. (DOE 1986b)

bulkhead A stone, steel, wood, or concrete wall-like structure designed to resist earth or water pressure. (EA)

burnup A measure of reactor fuel consumption, expressed either as the percentage of fuel atoms that have undergone fission or the amount of energy produced per unit weight of fuel in the reactor. (MP)

BWIP principal criteria Existing external principal technical and regulatory requirements that apply to the Basalt Waste Isolation Project (BWIP). They serve as the basis for translating the BWIP mission into the BWIP technical plans and the BWIP system specifications. (BWIP)

calcareous Consisting of or containing calcium carbonate. As combined with other rock names, the adjective indicates a considerable proportion, approximately 10% to 50%, of calcium carbonate. See caliche. (BWIP)

Caledonian A name commonly used for the early Paleozoic deformation in western Europe that created an orogenic belt, the Caledonides, extenting from Ireland and Scotland northeastward through Scandinavia.

calcine Material heated to a temperature below its melting point to reduce the water content and decompose soluble forms such as sulfate, nitrate, and carbonates by forming the often less soluble oxide form. (EA)

caldera A large basin-shaped volcanic depression, more or less circular in form. (EA, MP)

calibration A comparison of two instruments or measuring devices, one of which is a standard of known accuracy traceable to national standards, to detect, correlate, report, or eliminate by adjustment any discrepancy in accuracy of the instrument or measuring device being compared with the standard. (BWIP)

caliche Gravel, sand, or desert debris cemented by calcium carbonate; also the calcium carbonate itself. See calcareous. (MP)

Cambrian The oldest of the periods of the Paleozoic Era, extending from 570 to 500 m.y. ago. See geologic time scale. (EA)

candidate area A geologic and hydrologic system within which a geologic waste repository may be located. See areal extent and Table A-1 (appendix). (10 CFR 60)

candidate horizon Equivalent to the Cohassett flow, which is the preferred term. (BWIP)

candidate site An area, within a geohydrologic setting, that is recommended by the Secretary of Energy under Section 112 of the Nuclear Waste Policy Act of 1982 (the Act) for site characterization, approved by the President under Section 112 of the Act for characterization, or undergoing site characterization under Section 113 of the Act. (10 CFR 960.2)

canister (as related to radioactive materials) The primary metal or ceramic envelope for remote-handled solid transuranic waste, high-level waste, or spent fuel. The canister affords physical containment for the waste, but is not primarily designed to provide shielding.

canister array (as related to a repository) Obsolete. The geometric configuration of emplaced nuclear waste canisters; usually associated with terminal storage.

canistered waste (as related to waste package) Canister and contents, including waste form and any liner, stabilizer, or internal shielding material. (BWIP)

capable fault A fault that has exhibited one or more of the following characteristics: (1) movement at or near the ground surface at least once within the past 35,000 yr or movement of a recurring nature within the past 500,000 yr; (2) macroseismicity instrumentally determined with records of sufficient precision to demonstrate a direct relationship with the fault; or, (3) a structural relationship to a capable fault according to characteristics (1) and (2) such that movement on one could be reasonably expected to be accompanied by movement on the other. NOTE: A capable fault is a subset of an active fault. (10 CFR 50)

capillary fringe The zone immediately above the water table in which all or some of the rock pores or fractures are filled with water that is under less than atmospheric pressure and that is continuous with the water below the water table. (EA)

caprock A comparatively impervious layer of rock immediately overlying a fluid-bearing reservoir. (MP)

carbonaceous
(a) Said of a rock or sediment that is rich in carbon; coaly.

(b) Said of a sediment containing organic matter.

Carboniferous The Mississippian and Pennsylvanian periods combined, ranging from about 345 to about 280 m.y. ago; also, the corresponding system of rocks. In European usage, the Carboniferous is considered as a single period and is divided into upper and lower parts.

Cascadia One of the borderlands along the western margin of North America, partly at sea, partly inland. Most of the evidence adduced for the existence of Cascadia can now be otherwise interpreted.

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casing
(a) (noun) A liner in a shaft or borehole to prevent entry of loose rock, gas, or liquid, or to prevent the loss of circulating liquid into porous, cavernous, or fractured ground.

(b) (verb) The process of inserting casing into a borehole. (EA)

cask A shielded container used to transport radioactive material. See shipping cask.

cask-in-trench (or berm) An adaptation of the basic above-ground silo design where earth is used in addition to concrete to provide radiation shielding and physical protection. (MP)

cathode The electrode of an electrolytic cell at which reduction is the principal reaction. (Electrons flow toward the cathode in the external circuit.) Typical cathodic processes are cations taking up electrons and being discharged, oxygen being reduced, and the reduction of an element or group of elements from a higher to a lower valence state.

cation A positively charged ion. (MP)

Cenozoic The latest of the eras into which geologic time, as recorded by the stratified rocks of the Earth's crust, is divided; it extends from the end of the Mesozoic era to and including the present. See geologic time scale. (BWIP, MP)

certificate of compliance A written statement, signed by a qualified party, attesting that the items or services are in accordance with specified requirements (and accompanied by additional information to substantiate the statement). (BWIP, QA1, QA3)

certificate of conformance A document, signed by a qualified, authorized individual, certifying that items or services comply with specified requirements. (BWIP)

certification The action of determining, verifying, and attesting in writing to the qualifications of personnel, processes, procedures, or items in accordance with specified requirements. (BWIP)

certified test report A written and signed document, approved by a qualified party, that contains sufficient data and information to verify the actual properties of items and the actual results of all required tests. (BWIP, QA3)

change in scope A change in objectives, work plan, or schedule that results in a material difference from the terms of an approval to proceed previously granted by higher authority. (DOE 4700)

characteristic Any property or attribute of an item, process, or service that is distinct, describable, and measurable. (BWIP)

characterization, site (as related to the NWPA site selection) The process of identifying potential sites for mined geologic repositories through geologic and environmental studies as stated in Section 113 of the Nuclear Waste Policy Act of 1982. Detailed site characterization goes further to include the collection of all additional data necessary to submit a license application. See site characterization. (BWIP)

chemical grouts Different from cement grouts in that chemical grouts contain silicates, acrylamides, bentonite, lignins, etc. See also grout. (EA)

chemical processing Chemical treatment of materials to separate and recover specific usable constituents; at the Hanford Site, the separation by chemical means of plutonium, uranium, neptunium, and fission products from irradiated uranium fuel elements. This term is essentially equivalent to reprocessing. (BWIP)

chilled contact That part of a mass of igneous rock, near its contact with older rocks, that is glassy and finer grained than the rest of the mass, because of its having cooled more rapidly. (BWIP, EA)

chilled zone The border or marginal area of an igneous intrusion, characterized by a finer grain than the interior of the rock mass due to more rapid cooling. (BWIP, EA)

cladding (as related to nuclear fuel) A metal or ceramic covering that contains the fuel material.

cladding hulls The empty metal (or ceramic) casings that remain after spent fuel is removed from them for reprocessing. (EA)

class 1 - special groundwaters Those groundwaters that are highly vulnerable to contamination because of the hydrological characteristics of the areas under which they occur and that are also characterized by either of the following two factors:

(1) Irreplaceable source of drinking water (these include groundwater located in areas where there is no practical alternative source of drinking water (islands, peninsulas, isolated aquifers over bedrock) or an insufficient alternative source of groundwater for a substantial population).

(2) Ecologically vital, in that groundwater contributes to maintaining either the base flow or water level for a particularly sensitive ecological system that, if polluted, would destroy a unique habitat (e.g., those associated with wetlands that are habitats for unique species of flora and fauna or endangered species).

In the view of the U.S. Environmental Protection Agency, examples of hydrologic characteristics making a water source vulnerable to contamination are high hydraulic conductivity (e.g., Karst formations,

sand and gravel aquifers) or recharge conditions (e.g., a high water table overlain by thin and highly permeable soils). (EPA 1984)

NOTE: This term does not apply to the Hanford Site on the basis that the waters beneath the site are neither irreplaceable or ecologically vital. (BWIP)

classified document Any document containing information the disclosure of which could damage the national security of the United States or its allies. (DOE 5635.1)

classified information Any information that requires protection against unauthorized disclosure in the interests of the national defense and security or foreign relations of the United States pursuant to U.S. Statute or Executive Order. The term includes three classification categories: Restricted Data, Formerly Restricted Data, and National Security Information. Each classification category has degrees of importance denoted by the classification levels: Top Secret, Secret, or Confidential. (DOE 5636.4, DOE 1324.2, DOE 5635.1)

clast An individual constituent, grain, or fragment of a sediment or rock, produced by the physical disintegration of a larger rock mass. (EA)

clastic dike A tabular body of clastic material transecting the bedding of a sedimentary formation, representing extraneous material that has invaded the containing formation along a crack. (BWIP, EA)

clastic rock Any deposit that is composed of fragments of preexisting rocks or of solid products formed during the chemical weathering of such older rocks, and which have been transported mechanically to their places of deposition. (BWIP, EA)

clay A fine-grained natural, earthen material, usually exhibiting plastic properties, composed primarily of hydrous aluminum silicates. It may be a mixture of clay minerals and small amounts of nonclay materials or it may be predominantly one clay mineral. The type of clay is determined by the predominant clay mineral present (e.g., kaolin, montmorillonite, illite, halloysite). (BWIP, EA)

closed hydrologic basin A groundwater basin from which no water exits except by evaporation and evapotransition. (BWIP)

closure Final backfilling of the remaining open operational areas of the underground facility and boreholes after the termination of waste emplacement, culminating in the sealing of shafts. (10 CFR 960.2) NOTE: The U.S. Nuclear Regulatory Commission extends its definition to include method and disposal.

coccolith A general term applied to various microscopic calcareous structural elements of buttonlike places having many different shapes and averaging about 3 μm (1.2×10^{-4} in.) in diameter (though some have

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diameters as large as 35 μm (1.4×10^{-3} in.)), constituting the outer skeletal remains of a coccolithophore. Coccoliths are found in chalk and in deep-sea oozes of the temperate and tropical oceans, and were probably not common before the Jurassic.

coda-length magnitude The coda is the latter part of a seismogram following the early, identifiable body waves. Coda length is a measure of signal duration from the first-arriving wave to the time when the signal amplitude no longer exceeds some prescribed value (commonly twice the amplitude of background seismic noise).

Code of Federal Regulations (CFR) A codification of the general and permanent rules published in the Federal Register by the executive departments and agencies of the Federal Government. The Code is divided into 50 titles, which represent broad areas subject to Federal regulation.

coeval Originating or existing over the same period of time. (EA)

Cohassett flow A basalt flow within the Sentinel Bluffs sequence of the Grande Ronde Basalt. See Figures A-1 and A-7 (appendix). See candidate horizon or host rock. (BWIP)

cohesion Shear strength of a rock (soil or concrete) not related to interparticle friction. (EA)

cold (as related to radioactivity) Uncontaminated; free of radioactivity. (BWIP)

collar

(a) The intersection of a borehole or shaft with the surface from which it was drilled; this could be the ground surface for a surface borehole, or the wall of an opening for an underground borehole. (BWIP)

(b) A concrete ring or slab around the top section of a shaft used to support the opening and provide a working surface at ground level.

colloid A suspension of finely divided particles in a liquid. Suspended particles are not easily filtered out. (EA, MP)

colluvium A general term applied to the accumulation of loose, incoherent soil and rock material at the base of a slope. (EA)

colonnade That part of a basalt flow characterized by three- to eight-sided, well-defined subparallel columns. Column diameters are typically greater than 0.75 m (30 in.). (BWIP)

Columbia Plateau A geographic area situated in east-central Washington, western Idaho, and northeastern Oregon. It is defined by the lateral extent of the Columbia River flood basalts east of the Cascade Range.

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For BWIP applications, see Figure A-2 (appendix). See also "areal extent" in Table A-1 (appendix). (BWIP)

column-defining joints Cooling joints that form basalt columns. (BWIP)

column-subdividing joints Cooling joints that subdivide a column. (BWIP)

columnar entablature That part of a basalt flow with fracture abundance and column sites intermediate between those of entablature and colonnade. Fracture frequency is less than that of an entablature. Columnar-entablature exhibits jointing, which defines irregular blocks ranging from 6 to 20 cm (2.4 to 8 in.). Column diameters typically range from 40 to 75 cm (16 to 30 in.). (BWIP)

columnar fan A variation of the internal structure of a basalt flow in which the orientation of the columnar joints changes from generally parallel to make a fan-like, or radial pattern. (EA)

columnar jointing Jointing that breaks the rock into columns. The joints, which usually form a fairly well-defined prism that is hexagonal in cross section, are found in basaltic flows as a result of cooling of the igneous mass in which they occur. (BWIP, EA)

commercial high-level radioactive waste High-level radioactive waste produced in atomic energy activities other than for defense purposes. (MP)

commercial nuclear reactor A civilian nuclear powerplant operated to produce heat for generating electricity.

commercial waste Radioactive wastes generated in private, industrial, and other nongovernment facilities; principally wastes generated in power reactors and chemical processing plants, but also includes research laboratories and medical facilities. See also defense wastes (nuclear). (EA)

Commission The U.S. Nuclear Regulatory Commission or its duly authorized representatives. (10 CFR 60)

complexes In chemistry, any combination of cations with molecules or anions containing free pairs of electrons. An organic complex is a complex in which the cation is combined with an organic ligand. An inorganic complex is formed when the cation is combined with an inorganic ligand. Note that hydrates, although complexes, are usually not specified as such. (EA)

component A piece of equipment such as a vessel, piping, pump, valve, or core support structure that will be combined with other components to form an assembly. (BWIP, QA3)

component model A logically distinct subset of a model. (NRC 1983)

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compressional wave See P wave.

compressive strength The maximum compressive stress that can be applied to a material, under given conditions, before failure occurs. (EA)

computational brief The vehicle used for recording engineering, scientific, and technical calculations or analyses using information or data derived from any source, for input to other published/released documentation. The computational brief provides traceability from the referenced source document(s) to the published/released document. (IRM)

computer-aided design/computer-aided engineering (CAD/CAE) Computer-assisted technologies that provide drafting, design, and (or) engineering analysis capabilities of buildings, facilities, parts, circuits, assemblies, and (or) models, at stand-alone or graphics workstations connected to a computer. (IRM)

computer code A sequence of computer instructions to implement an algorithm representing the mathematical model of a system. NOTE: Definition for this term in NRC (1983) is "A set of computer instructions for performing the operations specified in a numerical model." (BWIP)

computer model The application of a code to a specific physical system by incorporating actual data representing the characteristics of that system. More simply, it is the use of a computer technique to solve a mathematical representation of a physical system or process. (BWIP)

concentration

(a) The collection of data from a number of links onto a smaller number of higher-capacity links, with the distribution of the return flow from fewer to more links. (IRM)

(b) The amount of a given substance in a stated unit of mixture, solution, or ore.

concentration guide (as related to radioactivity) The average concentration of a radionuclide in air or water to which a worker or member of the general population may be continuously exposed without exceeding appropriate radiation dose standards. See maximum permissible concentration. (BWIP)

conceptual design The design that is prepared for the Site Characterization Plan (SCP) and concentrates on the surface and underground systems, structures, and components that require site-characterization data. This design will provide information to ensure that data-gathering plans related to design are adequately included in the SCP. Data-accuracy requirements will be established and site-specific licensing issues related to site characterization will be identified.

conceptual design report Provides a detailed description and preliminary scope drawings of the proposed facility, including a cost estimate and schedule for design, procurement, and construction, for the guidance of the onsite architect/engineer in preparation of Title I and II Design. (BWIP)

conceptual model The quantitative and qualitative description of a system's or subsystem's physical characteristics and governing processes. In performance assessment, the term is generally applied such that greater emphasis is placed on the qualitative aspects of the system and (or) subsystem description; quantitative characteristics are usually emphasized in terms of numerical models or computer models. (BWIP)

concreting In tunneling, a method of support in which tunnel surfaces are coated with concrete containing reinforcing bar patterns. See shotcrete. (BWIP, EA)

conductivity, hydraulic See hydraulic conductivity.

configuration

(a) The functional and (or) physical characteristics of hardware and (or) software, as set forth in technical documentation and achieved in a product. (DOE 4700)

(b) For quality assurance (QA), the functional, physical, and procedural characteristics of an item, experiment, or document. Note that QA includes procedures as part of the configuration description. (BWIP)

confined aquifer A subsurface water-bearing region having defined, relatively impermeable upper and lower boundaries and containing confined groundwater whose pressure is usually greater than atmospheric pressure throughout. (BWIP, EA)

confinement As pertains to radioactivity, to keep radioactive material within some specified bounds. It differs from containment, in that no absolute physical barrier exists. (BWIP, EA)

confining pressure An equal, all-sided pressure, such as lithostatic pressure produced by overlying rocks in the crust of the Earth. (BWIP)

confining unit A body of impermeable or distinctly less permeable material stratigraphically adjacent to one or more aquifers. (10 CFR 960.2)

conglomerate A cemented clastic rock containing rounded or dissimilar fragments of gravel or pebble size. (BWIP, EA)

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consolidation The operation performed on spent fuel assemblies during which the upper and lower fuel-assembly tie plates are removed, the assembly spacer grids and any other assembly structural members are removed, and the fuel tubes are collected and formed into a closely packed bundle for insertion into a canister and (or) container. The nonfuel (less radioactive) structural members of the fuel assemblies will be reduced in volume and placed in containers for shipment and disposal. (MP)

constitutive law Any law that defines natural relationships or phenomena such as the dependence of strain on stress for solid materials or pressure-volume relationships for gases. (BWIP)

constitutive model A mathematical model of a material or a process that expresses its essential quality or nature. A constitutive model is expressed by constitutive equations that mathematically express the nature of the relationship between quantities of interest. For example, a linear elastic constitutive material model may be expressed as a set of constitutive equations establishing a linear elastic relationship between stress and strain. A nonlinear elastic constitutive model would use a different set of constitutive equations to express a nonlinear elastic relationship between stress and strain. (EA)

constraints Limitations that are placed on the system or subsystem by the design process, interrelated subsystems, environmental conditions within which the subsystem must function, and by the applicable regulations, codes, standards, policies, guidance, and other criteria that affect the subsystem and how it functions. (DOE 1986b)

construction Any combination of engineering, procurement, erection, installation, assembly, or fabrication activities involved to create a new facility or to alter, add to, or rehabilitate an existing facility. It also includes the alteration and repair (including dredging, excavating, and painting) of buildings, structures, or other real property. This does not involve the manufacture, production, finishing, construction, alteration, repair, processing or assembling of items categorized as personal property. (DOE 4700)

construction authorization Permit issued by the U.S. Nuclear Regulatory Commission to construct a nuclear facility. (BWIP)

construction completion date The date on which work normally performed by construction forces (including installation of equipment by operating contractors or others) is accepted by the Government. (DOE 4700)

construction management A wide range of professional services relating to the management of a project during the predesign, design, and (or) construction phases. The types of services include development of project strategy, design review relating to cost and time consequences, value engineering, budgeting, cost estimating, scheduling, monitoring of cost and schedule trends, procurement, observation to assure that

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workmanship and materials comply with plans and specifications, contract administration, labor relations, construction methodology and coordination, and other management efforts related to the acquisition of construction. (DOE 4700)

contact-handled waste (also contact-handled TRU waste) Containerized waste, usually in canisters (or metal drums), whose surface dose rate (less than 0.2 rem/h) is sufficiently low to permit direct handling. Such waste does not usually require shielding other than provided by its container. (BWIP, EA)

container The metal barrier portion of the waste package that is placed around the waste form.

container breach Failure of the container such that groundwater comes in direct contact with the high-level waste form.

containerized waste Container and contents including waste form and any liner, stabilizer, or shielding material. (BWIP, EA)

containment The confinement of radioactive waste within a designated boundary. (10 CFR 60.2)

containment integrity The ability of containment to meet applicable performance objectives. (BWIP)

containment period The period of repository history that begins at the time of container emplacement and ends at the time of container breach. A containment period of 300 to 1,000 yr is required by 10 CFR 60.13.

contaminated area A restricted area in which, under normal conditions, surface and airborne contamination levels may be greater than the permissible levels of 10 CFR 20. (DOE 1986b)

contamination

(a) The presence of radioactive material on the outside surfaces of a transportation vehicle, a shipping cask, repository equipment, or a waste container. (EA)

(b) Any undesirable foreign material on the surface of an item, in the atmosphere, or in process liquids or gases. (BWIP)

contamination (general) Undesirable radioactive material present on outside surfaces. This contamination can be either transferable or fixed. Radiation penetrating the walls of a waste package from within is not contamination. (BWIP)

contamination (material) The deposition or infiltration of radionuclides on or into an object, material, or area whereupon the area, material, or object is considered "contaminated." (BWIP)

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contamination, surface Removable or fixed radioactive material present on the outer surface of a container or cask. (BWIP)

contingency

(a) An amount budgeted to cover costs that may result from incomplete design, unforeseen and unpredictable conditions, or uncertainties. The amount of the contingency will depend on the status of design, procurement, construction, complexity, and uncertainties of the component parts of the project. Contingency is not to be used to avoid making an accurate assessment of expected cost. (DOE 4700)

(b) A special budget provision for unknown elements of cost within the defined project scope, such as estimate uncertainties due to design evolution, material pricing, labor productivity, crew makeup, estimate error or omission. NOTE: The U.S. Department of Energy-Richland Operations Office includes estimate uncertainties in its definitions. (DOE-RL)

contingency funds The portion of the project's authorized funds withheld for management control purposes rather than designated for the accomplishment of a specific task or set of tasks. It is not part of the funds identified for the project scope of work.

contingency plans Plans for emergency response, backup operations, and post-disaster recovery. (DOE 1360.2)

contingency projects Plant and capital equipment funded and line item projects for which different procedures are applied during the planning and budgeting process. Management of the design and construction phases is the same as for line item projects; however, the sequence of planning actions varies from line item projects. (DOE 4700)

continuous mining machine A machine equipped with a rotating cutting head with pick-like bits for cutting into rock and for dropping the cuttings into a collection device for loading into cars or conveyors. (EA)

contractor

(a) Any individual or organization entering into a contract to furnish items or services. It includes the terms vendor, supplier, subcontractor, fabricator, and subtier levels of these where appropriate. (BWIP)

(b) All persons, organizations, departments, divisions, and companies having contracts, agreements, or a memorandum of understanding with the U.S. Department of Energy (DOE). (DOE 4700)

(c) An entity in the private sector that enters into contracts with the government. NOTE: The DOE does not recognize contracts within the private sector when using this term. (DOE-RL)

controlled access area Any specific area into which entry by personnel is regulated by physical barrier or administrative procedure. (BWIP)

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controlled area (1) A surface location, to be identified by passive institutional controls, that encompasses no more than 100 km^2 (38.6 mi^2) and extends horizontally no more than 5 km (3.1 mi) in any direction from the outer boundary of the original location of the radioactive wastes in a disposal system; and (2) the subsurface underlying such a surface location. See also controlled area study zone and Figure A-3 (appendix). (40 CFR 191.12)

controlled area study zone (CASZ) The sum of all likely controlled areas for a repository in the reference repository location to be used until sufficient information is available to establish a controlled area within the constraints of 40 CFR 191. See Figures A-1 and A-3 (appendix). (BWIP)

controlled release period The period of repository history that begins at the time of container breach.

controlling corrosion mechanism The most important mechanism in determining the rate of a corrosion mode.

control material A substance added to waste forms containing fissile material to act as a neutron poison and prevent accidental criticality. (BWIP)

control zone A land area surrounding the repository to a distance designed to protect against the disruption of the repository system by man-induced activities (i.e., activities in this zone are "controlled"). See buffer zone. (BWIP)

convection Thermally induced movement of a liquid or gas (or solid in the case of volcanos). (BWIP)

convective cell In tectonics, a pattern of mass movement of mantle material in which the central area is uprising and the outer area is downflowing, due to heat variations. (BWIP)

cooling (spent fuel) Storage of fuel elements after discharge from reactors, usually under water, to allow for the decay of short-lived isotopes to acceptable radioactivity and heat emission levels. (BWIP, EA)

cooling joints A joint that is formed as a result of contraction during cooling of a basalt flow. See joint (geologic). (EA)

Cordillera Region of western North America from the eastern face of the Rocky Mountains to the Pacific Ocean.

core A cylindrical sample of rock obtained by use of a hollow drilling bit. (BWIP)

core disking Drilling of highly stressed hard rock may result in the formation of discs or wafers of relatively uniform thickness with concave-convex surfaces developed approximately normal to the axis of the core. The partings are independent of the rock structure with thickness of discs diminishing with increasing stress. Disc thickness has been observed varying from that equal to the core diameter to less than a fifth of the core diameter. (BWIP, EA)

core drill A mechanism designed to rotate and cause an annular-shaped rock-cutting bit to penetrate rock formations, produce cylindrical cores of the formations penetrated, and lift such cores to the surface, where they may be collected and examined. (BWIP, EA)

corrective action Those measures taken to rectify conditions adverse to quality and, where necessary, to preclude their recurrence. (BWIP)

corrosion The deterioration of a material, usually a metal, by reaction with its environment.

corrosion mechanism A discrete, single-chemical reaction or process which by itself or in combination with other mechanisms leads to a corrosion mode. For example, the reaction of oxygen with iron to form an oxide is a significant reaction in general corrosion. However, many more reactions are important in the overall rate of the general corrosion mode. Examples are: (1) the diffusion of metal ions or electrons through an existing oxide layer to react at the oxide surface, and (2) the rate of hydrogen evolution at the cathode.

corrosion mode The physical form or appearance that the material degradation assumes, such as general corrosion or pitting corrosion. The term "mode" is general in that it refers to the physical result.

corrosion potential (E_{corr}) The potential of a freely corroding surface in an electrolyte, relative to a reference electrode. Also called rest potential, open circuit potential, or freely corroding potential.

corrosion rate The rate at which corrosion proceeds, expressed as either weight change or penetration per unit time.

cost estimate A documented statement of costs estimated to be incurred to complete the project. Cost estimates provide baselines against which cost comparisons are made during the life of a project. (DOE 4700)

coulee A dry or intermittent stream valley of considerable extent. On the Columbia Plateau, coulees are long, steep-walled, trench-like gorges or vallies that are commonly abandoned overflow channels that temporarily carried meltwater from an ice sheet. (EA)

count (as related to radioactivity) The act of measuring radioactivity; the specified amount of radioactivity present. The count is related to disintegrations per second by an efficiency factor. (BWIP)

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counter An instrument used in conjunction with a detection probe to convert the radioactivity being monitored into a meaningful count or measure. (BWIP)

counts per minute The number of events per minute recorded by an instrument designed to detect radioactive particles; used especially to indicate the relative amount of radioactive contamination. (BWIP)

creep closure Closure or convergence of underground openings, especially openings in soft rocks such as clay or salt, of the surrounding rock under lithostatic pressure. Creep closure can also include joint sliding of rock masses, which is a time-dependent deformation response of mined openings. (BWIP)

Cretaceous The final period of the Mesozoic era (after the Jurassic and before the Tertiary period of the Cenozoic era), thought to have covered the span of time between 135 and 65 m.y. ago; also, the corresponding system of rocks.

crevice Any narrow opening in a surface or any open juncture between mating surfaces in which solutions can be trapped and not readily removed during rinsing or flushing operations (e.g., the annular spaces in threaded connections and socket assemblies, tube-to-tube sheet joints, and tube-to-tube support joints). (BWIP)

crevice corrosion A form of localized corrosion occurring at locations where easy access to the bulk environment is prevented, such as at the mating surfaces of metals or assemblies of metal and nonmetal.

crib

(a) A linear excavation about 4.6 m (15 ft) in depth along the bottom of which is laid a perforated pipe, after which the ditch is backfilled with broken rock or other loose material and then covered by soil and a membrane that is impermeable to liquids. The pipe is then used to distribute liquid wastes along the crib. (Formerly an underground lattice work of treated wooden timbers for the disposal of liquid waste.) (BWIP)

(b) As used in underground mining for roof support, a structure composed of frames of timber laid horizontally on one another, or of timbers built up as in the walls of a log cabin. (EA)

cristobalite A mineral (silicon dioxide) that is polymorphic with quartz. (BWIP)

criteria, design Quantitative limits placed on a design, assuring compliance with functional criteria. See design criteria. (BWIP)

criteria, functional Quantitative (and qualitative) limits placed on a design for acceptability within the framework of performance criteria of the waste management system. Originally called acceptance criteria. See design criteria. (BWIP)

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criteria, performance Qualitative limits placed on the geologic repository system for acceptability within the framework of Federal waste management regulations. See design criteria. (BWIP)

criteria, waste management A hierarchy of criteria that describes the sequential response by which the waste management system and its components meet the waste management objective. (BWIP)

criterion A standard rule or test by which something can be judged. (DOE 1986b, BWIP, EA)

critical The condition in which a material is undergoing nuclear fission at a self-sustaining rate; the critical mass of a material is that amount that will sustain a nuclear chain reaction when placed in an optimum configuration. Under just critical conditions there is an exact balance between the production of neutrons by fission and the loss of neutrons to the fissile materials present, to other absorbers in the system, and to escape from the system. (BWIP)

criticality The condition of supporting a (nuclear) chain reaction that occurs when the number of neutrons in one generation cycle equals the number generated in the previous cycle. (DOE 1986b)

critical pitting potential (E_{cp}, E_p) The lowest oxidizing potential at which pits nucleate and grow. It is dependent on the test method used.

crosscut
(a) A small passageway driven at right angles to the main entry to connect it with a parallel entry or air course.

(b) A level driven across the course of a vein or across the general direction of the workings. (EA)

cryosphere The part of the Earth's surface that is perennially frozen; the zone of the Earth where ice and frozen ground are formed.

crystalline rock An inexact but convenient term designating an igneous or metamorphic rock, as opposed to a sedimentary rock. Such rock consists almost wholly of mineral crystals or fragments of crystals. (BWIP, EA)

crystallization The formation of crystalline substance from solutions or melts. (McGraw-Hill 1984)

cumulative probability The level of certainty that a value of a random variable, within a value of interest, is less than or equal to the value of interest.

cumulative releases of radionuclides The total number of curies of radionuclides entering the accessible environment in any 10,000-yr period, normalized on the basis of radiotoxicity in accordance with

40 CFR 191. The peak cumulative release of radionuclides refers to the 10,000-yr period during which any such release attains its maximum predicted value. (10 CFR 960.2)

current density The current flowing to or from a unit area of an electrode surface.

damaged rock zone Those portions of the host rock mass surrounding any repository underground opening that have sustained mechanical degradation relative to natural (preconstruction) integrity of the repository isolation system as a result of repository excavation and operation. See Figure A-4 (appendix). (BWIP)

Darcy A unit of measurement of permeability equivalent to the passage of 1 cm^3 (0.06 in^3) of fluid, flowing in 1 s under 1 atm of pressure through a porous medium with a cross sectional area of 1 cm^2 (0.16 in^2) and a length of 1 cm (0.39 in). (EA)

Darcy's law A statement in fluid dynamics: the velocity of flow of a liquid through a porous medium due to a difference in pressure is proportional to the pressure gradient in the direction of flow. It is the product of the coefficient of permeability and the hydraulic gradient. See permeability and hydraulic gradient. (BWIP)

data

(a) (1) General term for numbers, letters, symbols, and analog quantities that serve as input for computer processing.
(2) Any representation of characters or analog quantities to which meaning, if not information, can be assigned.

(b) Numerical or qualitative values derived from scientific experiments.

(c) In application, any information recorded on any medium for the purpose of documenting results of tests, examinations, inspections, and experiments. For the Basalt Waste Isolation Project, data collection must be performed in accordance with approved procedures that could potentially be used in the decision-making process for site characterization and licensing.

data acquisition package (DAP) Obsolete. Use only in a historical context. Collections of raw data outputs from engineering, testing, and site characterization data acquisition activities for inclusion in the project technical data base and the Basalt Records Management Center.

data acquisition system (DAS) A centralized electronic data gathering system to be installed in a facility that will accept all raw data from testing equipment and transmit these data to a computer for entry into the BWIP computer data base.

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data base (as defined by the Conference of Data System Languages (CODASYL) A data base consists of all the record occurrences, set occurrences, and areas which are controlled by a specific schema. If an installation has multiple data bases, there must be a separate schema for each data base. Furthermore, the content of different data bases is assumed to be disjointed.) (IRM)

data base management system (DBMS) The collection of software required to use a data base and present different views of the data to the users and programmers. A group or collection of programs that allows the user to collect and manipulate data. (IRM)

data packages Supporting documents containing available data for Basalt Waste Isolation Project (BWIP) use. Data packages contain the data that are kept current, are traceable to documents that describe the collection or sources of the data, and are for use on all studies, design, modeling, subcontractor studies supporting the BWIP, and for interfacing with Office of Civilian Radioactive Waste Management participants.

daughter product A nuclide that results from radioactive decay. Also known as progeny. (BWIP)

decay (radioactive) The spontaneous transformation of one nuclide into a different nuclide or into a different isotope of the same nuclide. NOTE: Other forms of radioactivity such as isometric transition is usually included in model source terms (e.g., ^{90}Sr). (EA)

decay chain The sequence of radioactive disintegrations in succession from one nuclide to another until a stable daughter is reached. (BWIP, EA)

decay heat The thermal energy produced by radioactive disintegrations. (BWIP)

decollement Detachment structure of strata due to deformation, resulting in independent styles of deformation in the rocks above and below. (EA)

decommissioning The permanent removal from service of surface facilities and components necessary for preclosure operations only, after repository closure, in accordance with regulatory requirements and environmental policies. (10 CFR 960.2)

decontamination The removal of unwanted material (especially radioactive material) from the surface of or from within another material. (EA)

decontamination factor (DF) The reduction in radionuclide concentration or surface-level activity resulting from chemical processing, sorption, filtering, or cleaning, measured as the ratio of activity before and after processing. (BWIP)

deep continental geologic formations Geologic media located 304.8 m (1,000 ft) or more beneath the continents and isolated from biologic species and phenomena. Distinguished from ice sheets and sea floor geologic media. (BWIP)

deep hydrology This term appears to have a specific meaning at each of the Nuclear Waste Terminal Storage sites. At the Hanford Site, the term deep hydrology has been used to define the flow system beneath the basalts at a depth in excess of 3,000 m (10,000 ft). It has also been used to describe well drilling and groundwater studies at repository depths (i.e., 900 to 1,200 m (3,000 to 4,000 ft) below the ground surface). (BWIP)

defense high-level waste Waste (high-level) derived from atomic energy defense activities. NOTE: The Basalt Waste Isolation Project restricts this definition, it is suggested that "defense wastes" be used. (MP)

defense-in-depth A method of providing additional confidence in waste isolation by using relatively independent barriers. See multiple barrier system. (BWIP)

defense wastes (nuclear) Radioactive wastes generated in activities related to the national defense program, including the manufacture of nuclear weapons, the operation of naval reactors, and research and development at weapons laboratories. See also commercial waste. (BWIP)

definitive design (Title II) Continues the development of the project based on approved preliminary design (Title I). Definitive design includes any revisions required of the Title I effort; preparation of final working drawings, specifications, bidding documents, cost estimates, and coordination with all parties who might affect the project; development of firm construction and procurement schedules; and assistance in analyzing proposals or bids.

definitive work The effort on which a contractual agreement for the dollar value of the effort has been reached. (DOE 4700)

definitized work Same as definitive work.

deionized water Water that has undergone anion/cation exchange treatment in order to remove ionic impurities. (BWIP)

deliverable A report or product of one or more tasks that satisfies one or more objectives and must be delivered to satisfy contractual requirements. (DOE 4700)

Delphi process A technique of consensus-forming analysis through a structured process for eliciting expert opinion and for identifying the degree of consensus.

demonstrate To verify scale-up factors and economic and environmental viability for commercial application, through design, construction, and test and evaluation of large-scale energy systems in operational circumstances. (DOE 4700)

dendroclimatology The study of the patterns and relative sizes of annual growth rings of trees for paleoclimatologic data of the recent past.

dense interior Obsolete. Use only in a historical context. Preferred term is flow interior.

density The ratio of mass to volume, usually expressed metrically as grams per cubic centimeter. (BWIP)

density log A gamma-gamma log used to indicate the varying bulk densities of rocks penetrated in drilling by recording the amount of back-scattering of gamma rays. (EA)

denudation

(a) The sum of the processes that result in the wearing away or progressive lowering of the Earth's surface by various natural agents including weather, erosion, mass wasting, and transportation. (EA)

(b) The removal of all plant life from an area. (BWIP)

Department The U.S. Department of Energy or its duly authorized representatives. (40 CFR 191, BWIP)

Department of Energy (DOE) The U.S. Department of Energy. The U.S. Nuclear Regulatory Commission includes "or its duly authorized representaties." (10 CFR 60)

depleted uranium Uranium containing less than 0.7% ^{235}U. (BWIP)

deposition

(a) The laying down of rock-forming material by any natural agent (e.g., the mechanical settling of sediment from suspension in water). (EA)

(b) The constructive accumulation of material, through mechanical or chemical processes, normally into parallel layers.

design Specifications, drawings, design criteria, and component performance requirements for the natural and engineered components of the repository system. It includes design at each stage of design development (e.g., from conceptual design to final design). (BWIP)

design activities Data collection and analysis activities that are used in supporting design development and verification. They include general plans and detailed procedures for data collection and analysis, and

related information (e.g., test results and analysis). Data analysis includes the initial step of data reduction as well as broad-level systems analyses (e.g., performance assessments) that integrate many other data and analyses of individual parameters. (BWIP)

design bases
(a) Information which identifies: (1) the specific functions to be performed by the structures, systems, or components of a geologic repository; (2) assumptions regarding design controlling parameters; (3) the specific parameter values selected as a basis for the design; and (4) the supporting rationale for assumptions and parameter value selection.

(b) Information that establishes boundaries for design by specifying the functions to be performed by a structure, system, or component of a facility and the values or ranges of values for controlling parameters. (EA)

design basis event A credible accident or natural phenomenon (e.g., earthquake or flood) that is used to establish design basis because its consequences are the most severe of all those postulated for other credible accidents or phenomena. (EA)

design change Any revision or alteration of the technical requirements defined by approved and issued design output documents and approved and issued changes thereto. (BWIP)

design criteria Criteria prepared to provide the architect/engineer with the detailed design constraints for the facility, process, or system that is proposed. This document requires the U.S. Department of Energy-Richland Operations Office Construction Division approval and is the primary vehicle for conveying project requirements to the offsite architect/engineer for the preparation of Title I and II Design, replacing the Conceptual Design Report. See criteria, design; criteria, functional; criteria, performance. (BWIP)

design document control The collective term that defines Engineering Data Management responsibilities for implementing and operating the Design Document Control Systems and (or) Stations. (BWIP)

design input Those criteria, parameters, bases, or other design requirements on which detailed final design is based. (BWIP)

design life The period of time for which a structure, system, or component is designed to perform its intended function. The repository design life ends when the repository is of no further use, waste retrieval is no longer a concern, and closure and decommissioning begin. (EA)

design objective A requirement, derived from a licensing strategy, that must be met during the design process. Design objectives are also derived from information needs and place a constraint on the designer or specify design criteria that must be met.

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design output Documents (e.g., drawings, specifications and others) defining technical requirements of structures, systems, and components. (BWIP, QA1)

design process

(a) Technical and management processes that commence with identification of design input and that lead to and include the issuance of design output documents. (BWIP, QA)

(b) An iterative process of developing a geologic repository design from the preliminary stages where the level of uncertainty in design inputs is high, to a final stage where the level of uncertainty is low enough to meet established performance criteria.

design review Third-party evaluation of engineering documentation to ensure that requirements involving technical practices and intended applications are complete and correct. Final design reviews are convened for the purpose of obtaining approval signatures to engineering documents after completion of preliminary reviews and prior to official releases for implementation. (BWIP)

Design Review Board (DRB) A group of representatives (reviewers) from various functions (e.g., Research and Engineering; Quality Assurance; Health, Safety and Environment; Production Operations) selected by their functional management to review, comment, and provide recommendations relative to project documents. (BWIP)

design verification Acceptable methods for design verification include design reviews, alternate calculations, and qualification tests.

detail design Those design media necessary for fabrication, construction, and (or) installation of an equipment item or facility. These media shall include, but not be limited to, engineering drawings, changes, purchase specifications, construction specifications, and acceptance test procedures. (BWIP)

determination A decision by the Secretary of Energy that a site is suitable for site characterization for the selection of a repository site or that a site is suitable for the development of a repository, consistent with applications of the guidelines of 10 CFR 960, Subparts C and D, in accordance with the provisions set forth in Subpart B. (10 CFR 960.2)

deterministic analysis An analysis based on the premise that a specific effect results from a defined set of causes and assumptions. This method of analysis is based on causal relationships which assume a specific cause to effect correspondence between input parameters and the resultant outputs.

deterministic code A (computer) coded routine or algorithm that assumes a rigid input to output relationship.

deviatoric stress In the engineering discipline of rock mechanics, the deviatoric stress is the difference between the major principal stress (σ_1) and the minor principal stress (σ_3). (EA)

devitrification The process by which glassy substances lose their vitreous nature and become crystalline. (BWIP, EA)

dextral shear (tectonic term) A shear in which the portion on the far side appears to be offset to the right. See right-lateral offset. (EA)

diagenesis Recombination or rearrangement of a mineral resulting in a new mineral. (EA)

diapir A geologic flow structure, either a dome or an anticline, in which overlying rocks have been ruptured by the flow upwards of a plastic core material such as salt. (BWIP, EA)

diapir fold An anticline in which a mobile core, such as salt, has intruded into the more brittle overlying rock. Synonym for piercing fold or piercement fold. (BWIP)

diastem A relatively short interruption in sedimentation, involving only a brief interval of time, with little or no erosion before deposition is resumed; a depositional break of lesser magnitude than a paraconformity, or a paraconformity of very small time value. Diastems are not ordinarily susceptible of individual measurement, even qualitatively, because the lost intervals are too short; they are often deduced solely on paleontologic evidence.

diastrophism A general term for all movement of the crust produced by earth forces including the formation of continents and ocean basins, plateaus and mountains, folds of strata, and faults. (EA)

diatomaceous earth A fossil accumulation of diatoms (micro to macroscopic (small) shells of prehistoric sea animals), usually with some radiolaria and smaller amounts of foraminifera. (EA)

diffusion In general, the spontaneous dispersion of particles, liquids, gases, and solids. The Environmental Assessment (DOE 1986a) has constrained this to mean a solute-spreading phenomena important only at low groundwater velocities. (EA)

diffusion, mass Same as diffusion, molecular. (BWIP)

diffusion, molecular Movement of a contaminant due to the cumulative effect of the random motions of molecules. (BWIP)

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dike A tabular body of rock that cuts across the structure of adjacent rocks or cuts massive rocks, usually at a high angle of dip. See also sill. (EA)

diktytaxitic A rock texture characterized by numerous jagged, irregular vesicles bounded by crystals, some of which protrude into the cavities. (EA)

dip The angle at which a bed, stratum, vein, or any planar feature is inclined from the horizontal. The dip is at a right angle to the strike. (BWIP, EA)

dip-slip fault A fault in which the Earth displacement is parallel to the dip of the fault, and in which there is no horizontal component parallel to the strike. See strike-slip fault. (BWIP, EA)

diploxylon Bisaccate pollen, in which the outline of the sacci in distal-proximal view is discontinuous with the body outline so that the grain appears to consist of three distinct, more or less oval figures.

discharge point (or area) In groundwater hydraulics, the point (or area) where water comes out of an aquifer onto the surface. (BWIP, EA)

disc See disk.

discing See core disking.

disk A form of storage media used with computers.

disintegrations per minute The number of radioactive decay events occurring per unit time in a given amount of material. (BWIP)

dispersion A solute spreading or dilution phenomenon caused by mechanical mixing during groundwater movement and molecular diffusion. (EA)

displacement A chemical reaction in which an atom, radical, or molecule displaces and sets free an element of a compound. (McGraw-Hill 1984)

displacement (mechanical)

(a) The linear distance from the initial to the final position of an object moved from one place to another, regardless of the length of path followed.

(b) The distance of an oscillating particle from its equilibrium position. (BWIP)

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disposal The emplacement of high-level radioactive waste, spent nuclear fuel, or other highly radioactive material in a repository, with no foreseeable intent of recovery, whether or not such emplacement permits the recovery of such waste, and the isolation of such waste from the accessible environment. (10 CFR 960.2)

disposal package The primary container that holds, and is in contact with, solidified high-level radioactive waste, spent fuel, or other radioactive materials, and any overpacks that are emplaced at a repository. See also waste package. (MP)

disposal system Any combination of engineered and natural barriers that isolate spent fuel or radioactive waste after disposal. (40 CFR 191)

disqualifying condition A condition that, if present at a site, would eliminate that site from further consideration. (10 CFR 960.2)

dissolution A process of chemical weathering by which minerals and rocks are dissolved in water. (EA)

dissolution front The boundary of a geologic region within which rock is being dissolved. Relative to geologic waste disposal, the term particularly refers to the wedge-like leading edge of salt dissolution at the interface between salt formations. (BWIP)

distribution coefficient (Kd) The ratio of the concentration of a solute sorbed by ion-exchange substances (e.g., earth materials, particularly clays) to the concentration of the solute remaining in solution. A large distribution coefficient implies that the substance is readily sorbed and redissolved slowly. The concentration of a material in the solid phase (i.e., rock or sediment) (moles per gram) divided by the concentration of material in the aqueous phase (moles per liter). (BWIP, EA)

NOTE: Ion-exchange substances may include engineered materials.

disturbed rock zone Obsolete. This term should not be used as it is easily confused to mean either the disturbed zone (10 CFR 60) or damaged rock zone. Use a suitable modifier when discussing "disturbed rock zone" (e.g., blast-damaged zone). (BWIP)

disturbed zone That portion of the controlled area, excluding shafts, whose physical or chemical properties are predicted to change as a result of underground facility construction or heat generated by the emplaced radioactive waste such that the resultant change of properties could have a significant effect on the performance of the geologic repository. (10 CFR 960.2)

document Any record of information regardless of physical form or characteristics, including, but not limited to, the following (DOE 5635.1):

- All handwritten, printed, or typed matter.
- All painted, drawn, or engraved matter.
- All sound, magnetic, or electromechanical recordings.
- All photographic prints and exposed or developed film, still or motion pictures.
- Automated data processing input, memory, program, output information, or records such as punchcards, tapes, memory drums or disks, or visual displays.
- All reproductions of the foregoing by any process.

documentation

(a) The incorporation of appropriate identification on a publication such as document number, title, individual and corporate authors, contract number, whether revised or reprinted, volume number, conference information (title, date, place, sponsor(s)), responsible office and Departmental Element, date and place (city, state, and ZIP code) of publication, and any restrictions to its use such as security classification, proprietary restrictions, stock statement, and disclaimer language. (DOE 5635.1, DOE 1340.1A)

(b) Any written or pictorial information describing, defining, specifying, reporting, or certifying activities, requirements, procedures, or results. Documentation is not considered to be a quality assurance record until it satisfies the definition of a quality assurance record. (BWIP, QA3)

document control Process to assure that applicable documents are available at the location where they are to be used. Document control provides the following:

- Identification of documents to be controlled.
- Identification of assignment of responsibility for preparing, reviewing, approving, and issuing documents.
- Review of documents for adequacy, completeness, and correctness prior to approval and issuance. (QA1)

Document Control System System to control the distribution, revision, and storage of all Basalt Waste Isolation Project documents. (IRM)

dome (general) A dome-shaped landform or rock mass; a large igneous intrusion whose surface is convex upward with sides sloping away at low but gradually increasing angles; an uplift or an anticlinal structure,

either circular or elliptical in outline, in which the rock dips gently away in all directions. (BWIP, EA)

dose (radiation) A general term indicating the amount of energy absorbed per unit mass from incident radiation. See absorbed radiation dose. (BWIP)

dose equivalent (radiation) A concept used to describe the effectiveness of a given unit of absorbed radiation dose. The unit of dose equivalent is the rem. (EA)

dose rate Radiation dose received per unit of time. NOTE: The term "absorbed dose rate" is preferred. (BWIP, EA)

dosimeter An instrument for measuring accumulated radiation dose. Common dosimeters are thermoluminescent-type and pocket leaf electroscopes called pencil dosimeters. (BWIP)

downgradient The condition that results in movement of groundwater from an area of higher hydraulic pressure to one of lower pressure. (EA)

drift

(a) A horizontal or near-horizontal opening in mining and civil engineering driven from one underground working place to another. (BWIP)

(b) A general term for all rock material transported either by a glacier or by proglacial meltwater. (EA)

drill-and-blast A method of mining in which small-diameter holes less than 0.3 m (1 ft) are drilled into the rock and then loaded with explosives. The blast from the explosives breaks the rock away from the face such that the rock can be removed. The underground opening is expanded by repeated drilling and blasting. (EA)

drill hole A circular hole in rock made with a drill. (USBM) Synonymous with borehole.

drill-stem test A test of the productive capacity of a well when still full of drilling mud. The testing tool is lowered into the hole attached to the drill pipe and placed opposite the formation to be tested. Packers are set to shut off the weight of the drilling mud, and the tool is opened to permit the flow of any fluid into the drill pipe, where it can be measured. (EA)

drum (in nuclear waste disposal) A metal or composition (fiberglass) cylindrical container used for the transportation, storage, and disposal of waste materials. (BWIP)

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dry storage Cask, dry well, silo, and vault systems that are passive, modular, and low in maintenance and that provide an alternative for additional spent fuel storage at nuclear power plants that cannot accommodate reracking or rod compaction. (MP)

earthquake swarm A series of minor earthquakes, none of which may be identified as the main shock, occurring in a limited area and time. (EA)

earth sciences (as related to the Nuclear Waste Terminal Storage Program) Geology, geophysics, geohydrology, geochemistry, and other related disciplines supplying information to support establishment of a mined geologic repository. (BWIP)

Ecotone (GEOL) A transition zone that exists betwen two ecologic communities. Members of both communities may compete within the zone, thus yielding an apparent enrichment known as the edge effect.

eddy bar The accumulation of sand and gravel that results from a current eddy in a stream.

eddy diffusion Diffusion which occurs in turbulent flow, by the rapid process of mixing of the swirling eddies of fluid. Also known as turbulent diffusion. (BWIP)

effective porosity The amount of interconnected pore space and fracture openings available for the transmission of fluids, expressed as the ratio of the volume of interconnected pores and openings to the volume of rock. (10 CFR 960.2)

effluent Treated or untreated gaseous or liquid material that flows into the environment. (DOE 1986b)

Eh A measure of the oxidation-reduction potential (volts); the difference in potential measured in a cell having both oxidized and reduced form of an element (measured) and the standard hydrogen electrode potential. (Eh also can be expressed as pE, which is defined as the negative logarithm of the electron activity.) (BWIP, EA)

elastic modulus (modulus of elasticity) The ratio of stress to the unit deformation of material when a stress is exerted on the material.

electrical resistivity The electrical resistance offered by a material to the flow of current, times the cross-sectional area of current flow and per unit length of current path; the reciprocal of the conductivity. Also known as resistivity, specific resistance. (BWIP)

electrochemical cell An electrochemical system consisting of an anode and a cathode in metallic contact and immersed in an electrolyte. (The anode and cathode may be different metals or dissimilar areas on the same metal surface.)

electrode An electronic conductor used to establish electrical contact with an electrolytic part of a circuit.

electrolyte A chemical substance or mixture, usually liquid, containing ions that migrate in an electric field.

emplacement (as related to waste management) The act of placing containerized waste in a prepared position. (EA)

emplacement medium The material in which a repository is built and into which the waste will be placed. See host rock. (BWIP, EA)

emplacement shell Outer shell of the waste package. (BWIP)

emplacement site (as related to waste management) The prepared position where the assembled waste package resides. (EA)

end function A work breakdown structure identifier prescribed by the Office of Civilian Radioactive Waste Management for uniform organization of program participants.

en echelon A steplike (parallel but unaligned), overlapping, or staggered arrangement, as applied to geologic features. (BWIP)

engineered barrier An addition to the geological environment which has been designed, fabricated, and emplaced to minimize or preclude radionuclide transport. (EA)

engineered-barrier system

(a) The manmade components of a disposal system designed to prevent the release of radionuclides from the underground facility or into the geohydrologic setting. Such term includes the radioactive-waste form, radioactive-waste canisters, materials placed over and around such canisters, any other components of the waste package, and barriers used to seal penetrations in and into the underground facility. (10 CFR 960.2)

(b) The waste packages and the underground facility. (10 CFR 60.2)

engineered barrier system boundary The envelope of the underground facility. For the purpose of the Site Characterization Plan, the boundary for release rate evaluations is conservatively chosen to coincide with the surfaces of the excavations within the underground facility.

engineered system The underground facility, waste package, shaft and tunnel seals, tunnel backfill, and disturbed rock zone caused by excavation or from the high heat pulse generated by the emplaced radioactive waste.

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engineering development Systematic use of the knowledge and understanding gained from research and technology development to achieve the detailed design, construction and test for performance, producibility, and reliability of energy system prototypes, pilot plants, and research facilities. (DOE 4700)

engineering scale Refers to the size of tests being performed. Engineering-scale tests are conducted as an intermediate step between small-(bench-) scale laboratory tests and semi- or full-scale tests that are conducted at field test facilities or in underground facilities in situ. (BWIP)

enriched uranium Uranium containing more than 0.72% ^{235}U. (BWIP)

entablature That part of a basalt flow, composed of irregular blocks, 1 to 20 cm (0.4 to 8 in.) in diameter, separated by hackly jointing. The irregular blocks are often contained within relatively small, subparallel columns with three to eight sides. Columns within the entablature are generally less than 40 cm (16 in.) in diameter. In some entablatures, no columnar structures are apparent. (BWIP)

entity-relationship A method of data modeling for conceptually organizing a set of data that explicitly displays one set of categories into which the entitites contained in the data set may be sorted and also explicitly displays the logical relationships among those categories.

envelope Limits to the range of parameters of a system. (BWIP)

environmental (considerations of) Air and water quality, land disturbances, ecology, climate, public and occupational health and safety, and socioeconomic(s) (including nonavailability of critical resources and institutional, cultural, and aesthetic considerations). For conciseness, these are normally referred to as environmental, health, and safety considerations. (DOE 4700)

Environmental assessment (EA) The document required by Section 112(b)(1)(E) of the Nuclear Waste Policy Act of 1982. (10 CFR 960.2)

Environmental Evaluation A brief document prepared by the U.S. Department of Energy to verify that no significant impact will result from proposed activities. (BWIP)

Environmental impact statement (EIS) The document required by Section 102(2)(c) of the National Environmental Policy Act of 1969. Sections 114(a) and 114(f) of the Nuclear Waste Policy Act of 1982 include certain limitations on the National Environmental Policy Act requirements as they apply to the preparation of an environmental impact statement for the development of a repository at a characterized site. (10 CFR 960.2)

environmental report A detailed document that is submitted to the U.S. Nuclear Regulatory Commission as part of the license application. The document provides a detailed description of the expected environmental impacts associated with a proposed construction project, in this case a nuclear waste repository in basalt. (BWIP, EA)

environmentally assisted cracking Brittle fracture of a normally ductile material in which the corrosive effect of the environment is a causative factor. Environmentally assisted cracking is a general term that includes stress corrosion cracking and hydrogen embrittlement.

Eocene An epoch of the lower Tertiary period, after the Paleocene and before the Oligocene; also, the corresponding worldwide series of rocks. It is sometimes cnsidered to be a period, when the Tertiary is designated.

eolian Of, related to, formed by, or deposited from the wind or currents of air. Often applied to sand dunes that have been accumulated by the wind. (BWIP, EA)

epeirogeny The broad movement of uplift and subsidence which affects whole or large portions of continents or ocean basins. (BWIP)

ephemeral stream A stream that flows in direct response to precipitation, and is dry at some or most of the time during the year. (BWIP, EA)

epicenter The point on the Earth's surface directly above the focus or place of origin of an earthquake. (BWIP)

epochs A geologic-time unit longer than an age (geochron) and shorter than a period (geochron), during which the rocks of the corresponding series were formed.

equant Said of crystal having the same or nearly the same diameter in all directions. (Bates and Jackson 1984)

erosion The wearing away of soil and rock by weathering, mass wasting, and the action of streams, glaciers, waves, wind, and underground water. See denudation. (EA, MP)

eugeosyncline A geosyncline in which volcanism is associated with clastic sedimentation. (BWIP)

eustatic Pertaining to worldwide changes of sea level that affect all the oceans. See glacio-eustatic. (EA)

evaluation The act of carefully examining the characteristics of a site in relation to the requirements of the qualifying or disqualifying conditions specified in the guidelines (10 CFR 960) of Subparts C and D. Evaluation includes the consideration of favorable and potentially adverse conditions. (10 CFR 960.2)

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evaporite Sedimentary rock deposited from aqueous solution as a result of extensive or total evaporation of the solvent (e.g., rock salt and gypsum). (MP)

evapotranspiration A term embracing that portion of the precipitation returned to the air through direct evaporation or by transpiration of vegetation. (MP)

event An occurrence that impacts project or system operation, progress, schedule, or cost. (BWIP)

exceedence probability The probability that an event will occur during a specific preclosure exposure time. For seismic events, "exceedence probability" means the probability that a specified level of ground motion of specified social or economic consequences of earthquakes will be exceeded at a site or in a region during a specified exposure time.

exosolution The process whereby an initially homogeneous solid solution separates into two (or possibly more) distinct crystalline phases without addition or removal of material (i.e., without change in the bulk composition). It generally, though not necessarily, occurs on cooling.

exothermic reaction A chemical reaction that yields heat. (BWIP)

expected Assumed to be probable or certain on the basis of existing evidence and in the absence of significant evidence to the contrary. (10 CFR 960.2)

expected repository performance The manner in which the repository is projected to function, considering those conditions, processes, and events that are likely to prevail or may occur during the time period of interest. (10 CFR 960.2)

experimental material (controlled) The controlled starting material (e.g., basalt specimen, standard backfill materials, metal coupon, water sample) used in a laboratory experiment or test sequence.

experimental sample Any experimental material upon being measured or analyzed prior to or after being used in a laboratory experiment.

Exploratory Shaft (ES) Obsolete. A subsurface excavation composed of tunnels and rooms in the host rock in the immediate vicinity of the proposed repository shafts and at the depth that a repository would be built. The shafts will be large enough to allow people and test equipment to be transported from the surface to the subsurface excavations and will allow detailed study of the host rock including lateral exploratory drilling. (MP)

Exploratory Shaft Facility (ESF) An installation composed of shafts, underground openings, and surface support facilities to provide access to the candidate horizon for the purposes of in situ testing for site characterization, and constructibility testing.

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Exploratory Shaft Phase I Obsolete. Phase I of the Exploratory Shaft consists of a finished shaft down to the reference repository horizon with breakout to include an excavated breakout station at that horizon. The surface facilities (e.g., hoist headframe, emergency hoist) are also included. The purpose of the Phase I portion is site characterization. (BWIP)

Exploratory Shaft Phase II Obsolete. Phase II of the Exploratory Shaft consists of several hundred feet of rooms extending from the breakout station included as part of Phase I. Additional tunneling and a second shaft would also be included as a later part of Phase II and would primarily be used for engineering tests. (BWIP)

exposure
(a) The condition of being made subject to the action of radiation. (EA)

(b) The general surroundings of a site, with special reference to its openness to winds and sunshine. See also outcrop. (McGraw-Hill 1984)

extensometer An instrument used to determine linear strain. (BWIP, EA)

extraction A chemical process for selectively removing materials from solutions. (BWIP)

extraction ratio The ratio of the amount of rock removed to the total amount of rock available within a given area. (EA)

fabrication The act of constructing or manufacturing, usually from diverse and standardized parts.

facies The aspect, appearance, and characteristics of a rock unit, usually reflecting the conditions of its origin, especially as differentiating the unit from adjacent or associated units. (EA)

facility Any structure, system, or system component, including engineered barriers, created by the DOE to meet repository-performance or functional objectives. (10 CFR 960.2)

fanglomerate
(a) A mixture of heterogeneous sediments originally deposited in an alluvial fan and subsequently cemented into rock. (BWIP)

(b) A sedimentary rock consisting of slightly waterworn, heterogeneous fragments of all sizes, originally deposited in an alluvial fan and subsequently cemented into a firm rock. (EA)

far field Obsolete. It is viewed as approximating the zone outside of the damaged rock zone to the outer edge of the controlled area study zone. Use only in a historical context. (BWIP)

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fault (geologic) A fracture or a zone of fractures along which there has been displacement of the sides relative to one another parallel to the fracture or zone of fractures. (10 CFR 960.2)

fault block
(a) A structural unit of the Earth's crust that is formed by faulting and is bounded completely or in part by faults. This structure behaves essentially as a unit during tectonic activity. (EA)

(b) A crustal unit formed by block faulting; it is bounded by faults, either completely or in part. (MP)

fault escarpment See fault scarp. (EA)

fault gouge A soft, uncemented pulverized clay or claylike material, commonly a mixture of minerals in finely divided form, found along some faults or between the walls of a fault, and filling or partly filling a fault zone; a slippery mud that coats the fault surface or cements the fault breccia. (EA)

fault plane The plane along which faulting has taken place. (EA)

fault scarp The cliff or escarpment formed by a fault that reaches the Earth's surface. (EA)

fault system A system consisting of two or more fault sets that were formed at the same time. (EA)

faulting The process of fracturing and displacement that produces a fault. (10 CFR 960.2)

favorable condition A condition that, though not necessary to qualify a site, is presumed, if present, to enhance confidence that the qualifying condition of a particular guideline can be met. (10 CFR 960.2)

final procurement and construction design The design that is complete for the one site selected from the three characterized candidate sites. It will develop the final (working) drawings and specifications for procurement and construction. The completion of this design will match the completion of the Title II design effort for the entire repository.

feldspar A group of silicate minerals that make up about 60% of the outer 15 km (9.3 mi) of the Earth's crust; they are silicates of aluminum with the metals potassium, sodium, and calcium, and rarely, barium. (BWIP)

felt area See macroseismic region.

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fertile isotope A nuclide that is capable of being transmuted, by absorption of a neutron and subsequent decay, into a fissile nuclide. An example is ^{238}U which is transmuted to plutonium in production reactors. (BWIP)

field tests All tests that are conducted in selected geologic formations at the Earth's surface or below ground (but not at repository depth at the repository site location). These include tests during site exploration and specialized tests at field test sites to verify hydrogeologic conditions but not in situ tests. See in situ tests. (BWIP)

filler The nonradioactive portion of the waste form which chemically or mechanically limits the mobility of radionuclides by dispersion or leaching. Also called binder, matrix, or immobilizing agent. (BWIP, EA)

final design Approved design output documents and approved changes thereto. (BWIP, QA1)

Final Environmental Impact Statement An environmental impact statement that has completed the public hearing process and has been issued by the responsible governmental agency. (BWIP, EA)

final procurement and construction design The design that will develop the final (working) drawings and specifications for procurement and construction. The completion of this design phase will match the completion of the Title II design effort for the entire repository. This design phase will emphasize the completion of design of ancillary support items, final design refinement for the items necessary to demonstrate compliance with the design criteria and performance objectives of 10 CFR 60, the development of construction bid packages for all systems, and the development of final procurement and construction schedules.

Final Safety Analysis Report A detailed safety document issued by the U.S. Nuclear Regulatory Commission (NRC) to discuss and resolve safety questions pertaining to a nuclear project. The document is considered final after public hearings have been completed and NRC issues the document. (BWIP, EA)

final site selection The process of choosing one of several banked sites for a high-level waste repository. This will include a comparison of their environmental, technical, and institutional factors. The result will be a license application to be submitted to the U.S. Nuclear Regulatory Commission. (10 CFR 960)

finding A conclusion that is reached after evaluation. (10 CFR 960.2)

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finite-element computer code A computer code that uses the finite-element method. The finite-element method is a method of numerical analysis that divides a region of interest into discrete elements and represents the behavior of the elements with a set of simultaneous equations. Solution of the set of equations yields the behavior at discrete points within the region of interest. (EA)

first-order fold An original stage fold larger than subsequent folds that may occur on it. See second-order fold. (EA)

fissile material One of several actinides capable of being split by absorption of low energy (e.g., thermal) neutrons with an attendant release of energy and additional neutrons. (BWIP)

fission The division of atomic nuclei into nuclides of lower mass, usually accompanied by the emission of gamma rays, neutrons, and significant energy. (EA)

fissionable Capable of being fissioned by absorption of a neutron of appropriate energy. (BWIP)

fission product A nuclide produced by the fission of a heavier element. (BWIP, EA)

fission-product gases Radioactive fission products in gaseous form, specifically krypton, xenon, iodine, and tritium. (BWIP)

fissure A fracture or a crack in the Earth's surface, along which there is a distinct separation. (EA) In addition, fissures are perpendicular to the surface fracture; an open joint.

flat-jack test Testing apparatus used for determination of in situ stresses or rock mass deformability. (EA)

flexure-flow fold A fold in which the mechanism of folding is flow within layers, resulting in thickening of higher areas and thinning of limbs. (EA)

flooding potential Areas susceptible to flooding by precipitation, wind, or seismically induced floods (i.e., those resulting from dam failure, river blockage or diversion, or distantly or locally generated waves) are considered to have a flooding potential. (BWIP, EA)

flood plain The lowland and relatively flat areas adjoining inland and coastal waters including flood-prone areas of offshore islands and including at a minimum that area subject to a 1% or greater chance of flooding in any given year. (10 CFR 60, BWIP, EA)

flow (geologic in terms of this document) See basalt flow.

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flow bottom The lower portion of a basalt flow composed of a basal chilled zone, and some combination of breccia, ropy, vesicular/vuggy, or rubbly basalt. A pillowed zone, when present, occurs typically at the flow bottom. Where pillows are absent, flow bottoms are generally 0.5 m (1.5 ft) or less in thickness. When vesiculation is part of the flow bottom feature, the upper limit of the flow bottom is defined as the point where vesiculation decreases to less than two volume percent. The lower limit of flow bottom is the contact of the flow with the underlying flow. See flow contact. (BWIP)

flow contact A flow contact is the surface between the base of a flow and the underlying material. This surface can commonly be located by identifying the chilled, glassy rind or base of the flow bottom. See flow top, flow bottom. (BWIP)

flowing artesian (well) Where the water level rises above the ground surface. (BWIP)

flow interior The zone within a basalt flow between the base of the flow top zone and the top of the flow bottom zone that includes both the entablature, columnar-entablature, and colonnade. (EA)

flow path The model trajectory of a hypothetical groundwater particle from a release point at the underground facility to the boundary of the model system. (BWIP)

flow structure The structure of igneous rocks, generally but not necessarily restricted to volcanic rocks, in which the stream or slow lines of the magma (as evidenced by the orientation of the rock crystals) are revealed by alternating bands or layers of differing composition, crystallinity, or texture. (BWIP, EA)

flow top The upper portion of a basalt flow composed of basalt breccia, basalt rubble, ropy basalt, slabby basalt, clinkery or scoriaceous zones, vesicular or vuggy zones, or any combination of the above. Flow top can range from dark and glassy to an oxidated reddish-brick color. The lower limit of flow top zones, which are vesicular, is defined as that point where vesiculation decreases to less than 2 vol%. (BWIP)

fluid content The degree of saturation of the intergranular space in rocks by organic fluids, gases, and water; the state of hydration of the rock minerals. (BWIP, EA)

fluid inclusion Fluids trapped within a small opening in a rock mass. (BWIP)

fluvial Of or pertaining to streams and rivers; produced by stream or river action. (BWIP, EA)

flux Rate of flow into or out of a surface (quantity per unit area per unit time). (EA)

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focal mechanism solution A double-couple solution obtained using first motion of arrival of P waves at a particular seismic-recording station. (EA)

fold A bend or flexure in a layer or layers of rock. Usually applies to a single strong flexure with steeply inclined sides. (BWIP, EA)

fold belt A linear region that has been subjected to folding and deformation. (BWIP, EA)

foraminifera An order of protozoa in the subclass Sarcodina characterized by the presence of a test of one to many chambers composed of secreted calcite (rarely silica or aragonite) or of agglutinated particles. Most foraminifers are marine, but freshwater forms are known.

formation The basic rock-stratigraphic unit in the local classification of rocks. It consists of a body of rock generally characterized by some degree of internal lithologic homogeneity or distinctive features. (EA)

fractionization The process of removing specific constituents (such as strontium and cesium) from liquid waste by chemical or physical means. It is sometimes used to describe a method for separating the actinides, individually or as a group, from a fission product containing waste stream. (BWIP)

fracture A general term for any break or discontinuity in a rock caused by mechanical failure resulting from stress, whether or not it causes displacement on either side large enough to be visible to the unaided eye. It may be a joint, fault, or fissure caused by geological or mechanical process and can range from microscopic to macroscopic and megascopic scales. (BWIP, EA)

fracture mechanics A quantitative analysis for evaluating fractural process occurring within materials in terms of applied stress, crack length, and specimen geometry.

fuel assembly A unit assemblage of nuclear reactor fuel, consisting of fuel rods, rod ends, and structural supports. (EA)

fuel basket The holder or transfer mechanism for handling and storage of spent fuel in reactor facilities. (BWIP)

fuel cycle The processing steps that convert uranium ore to nuclear fuel and provide for its disposal, including mining, milling, conversion, enrichment, fuel element fabrication, irradiation in reactors, reprocessing (if desired), storage, and disposal. (MP)

fuel element A structure into which fissionable material is fabricated for use in a reactor. (BWIP)

fuel reprocessing The process whereby spent fuel is dissolved, waste materials are removed, and reusable materials are segregated for reuse. (EA)

fuel rod A long slender, cylindrical tube of stainless steel or Zircaloy containing nuclear fuel in the form of uranium oxide fuel pellets. Also called fuel pin. (EA)

functional characteristics Those attributes of a repository or its structures/systems/components which determine its performance with respect to safety and design criteria established in the Code of Federal Regulations, Regulatory Guides, or other Federal regulatory documents. (BWIP)

functional design criteria (FDC) A summary description of systems, processes, or facilities which documents minimum requirements. These described requirements form the basis of and provide limitations governing design for a safe and operable facility, complete and adequate for its intended purpose. The FDC represents the technical baseline for the described program elements, used as the basis for conceptual design, and requires DOE-RL Program Division approval.

galvanic corrosion Corrosion associated with the current resulting from the electrical coupling of dissimilar electrodes in an electrolyte.

gamma (abbreviated version of gamma radiation) An ionizing electromagnetic ray or photon of short wavelength. See gamma ray. (BWIP)

gamma flux The number of photons per square centimeter per second. (BWIP)

gamma log Record of gamma radiation intensity in strata penetrated by a test well or borehole, measuring both artificial and natural gamma radiation. (BWIP)

gamma ray Short-wavelength (less than 10 mm (2.54 in.)) electromagnetic radiation emitted during the radioactive decay of certain nuclides. Gamma rays are highly penetrating. (MP)

general corrosion A form of deterioration that is distributed more or less uniformly over a surface area.

general environment (as used by the U.S. Environmental Protection Agency) The total terrestrial, atmospheric, and aquatic environments outside sites within which any operation associated with the management and storage of spent nuclear fuel, high-level, or transuranic radioactive wastes is conducted. (BWIP)

geochemistry The study of the distribution and amounts of the chemical elements in minerals, ores, rocks, soils, water, and the atmosphere and the chemical interactions between these phases. (EA, MP)

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geochronology The study of time in relationship to the history of the Earth. (EA)

geodetic survey Survey in which account is taken of the shape and size of the Earth and corrections are made for earth curvature. (EA, MP)

geodolite An electro-optical distance-measuring instrument in which a modulated laser beam is projected from the instrument to a remote reflector from which it is returned to the instrument. Geodolite is a trade name. (EA)

geoelectric layer One particular layer in a vertical distribution of layer thicknesses, electrical conductivities, dielectric permissivities, and magnetic permeabilities that are descriptive of the subsurface. (EA)

geoengineering The application of geologic data, principals, and techniques to the study of naturally occurring rock and soil materials or groundwater for the purpose of assuring that geologic factors affecting the location, planning, design, construction, operation, and maintenance of engineering structures and the development of groundwater resources are properly recognized and adequately interpreted, utilized, and presented for use in engineering practice. (EA)

geohydrologic Pertaining to groundwater and its movements through the geologic environment. (BWIP, MP)

geohydrologic setting The system of geohydrologic units that is located within a given geologic setting. (10 CFR 960.2)

geohydrologic system The areal and stratigraphic extent of a geohydrologic unit. It comprises the rock volume and natural or man-induced events affecting flow dynamics within a geohydrologic unit. (BWIP)

geohydrologic unit An aquifer, a confining unit, or a combination of aquifers and confining units comprising a framework for a reasonably distinct geohydrologic system. (10 CFR 960.2)

geohydrology The study of the character, source, and mode of occurrence of underground water. (BWIP)

geologic (factors) In the Civilian Radioactive Waste Management Program, factors such as the depth, thickness, and lateral extent of the host rock; ground motion, faults, igneous activity, uplift and subsidence, and dissolution; rock structure and characteristics, groundwater flow and travel times; chemical interactions; resource potential; surface water bodies; and terrain. (MP)

geologic containment The system of rocks, hydrologic conditions, and tectonic stability that inhibits or prevents spread of radioactive waste from the repository. (BWIP)

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geologic disposal Placement of radioactive waste in deep stable geologic formations. (MP)

geologic environment (as related to a repository) That volume of the Earth's crust which is affected by repository construction, operation, and decommissioning. The disturbed rock contained in the geologic environment of a repository may be part of a potential transport path to the biosphere. (BWIP)

geologic isolation Placement of nuclear waste or spent fuel in a deep, stable geologic formation.

geologic medium A body of rock characterized by lithologic homogeneity. (10 CFR 60, BWIP)

geologic repository A system, requiring licensing by the NRC, that is intended to be used, or may be used, for the disposal of radioactive waste in excavated geologic media. A geologic repository includes (1) the geologic-repository operations area and (2) the portion of the geologic setting that provides isolation of the radioactive waste and is located within the controlled area. (10 CFR 960.2)

geologic-repository operations area A radioactive-waste facility that is part of the geologic repository, including both surface and subsurface areas and facilities where waste-handling activities are conducted. (10 CFR 960.2)

geologic setting The geologic, hydrologic, and geochemical systems of the region in which a geologic-repository operations area is or may be located. (10 CFR 960.2)

geologic time scale A system of subdividing geologic time, usually presented in the form of a chart showing the names of the various divisions of time, stratigraphy, or rock as currently understood (Table A-2, appendix). (BWIP, EA)

geomechanics That branch of geology dealing with the response of earth materials to the application of deforming forces and embraces the fundamentals of structural geology. (EA, MP)

geomorphic Of or relating to the form of the Earth or its surface features. (MP)

geomorphic processes Geologic processes that are responsible for the general configuration of the Earth's surface, including the development of present landforms and their relationships to underlying structures, and are responsible for the geologic changes recorded by these surface features. (10 CFR 960.2)

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geomorphology The branch of geology that deals with the general configuration of the Earth's surface; specifically the study of the classification, description, nature, origin, and development of landforms. (EA)

geophone See seismometer.

geophysical Pertaining to the properties of the Earth related to its structure, composition, and development. (EA, MP)

geophysical anomaly An area or portion of information derived from a geophysical survey that is different in appearance from the general pattern of the information. (EA)

geophysical log A graphic record of measured or computed geophysical data. Types of geophysical logs include sonic, density, natural gamma, neutron, and porosity logs. (EA)

geophysical survey The use of one or more geophysical techniques such as earth currents, electrical, gravity, magnetic, and seismic to gather information on the subsurface geology. (BWIP, EA)

geophysics Study of Earth by quantitative physical methods including specialties (e.g., tectophysics, seismology, and engineering geophysics).

geosphere Any of the so-called spheres or layers of the Earth, including the atmosphere, lithosphere, and hydrosphere. (BWIP)

geosyncline A large, generally linear trough that deeply subsided over a long period of time and in which a thick sequence of stratified sediments accumulated. (EA)

geotechnical Pertinent to the application of scientific methods and engineering principles to the acquisition, interpretation, and use of knowledge of the materials in the Earth's crust. (EA)

geothermal gradient The rate of increase of temperature of the Earth with depth. (BWIP, EA)

geothermal resource Thermal energy from the Earth's internal heat, commonly in the form of heated water, that exists in sufficient quantity to be economically feasible to remove for use.

geotransport Movement of radionuclides through subsurface soils and rocks, especially movement with the groundwater. Used in contrast to biotransport. (BWIP, EA)

getter (physical) A material that selectively sorbs and holds particular elements. This term is particularly applicable to engineered barrier systems. (Adapted from metallurgical processes wherein a getter is used to remove impurities.) (BWIP, EA)

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glacio-eustatic Pertaining to worldwide changes in sea level resulting from successive withdrawal and return of water to the oceans, which occurs during the growth and melting of ice sheets. See eustatic. (EA)

glaciofluvial Of, pertaining to, produced by, or resulting from combined glacial meltwaters. (BWIP, EA)

glomerocryst An aggregate of crystals of the same mineral. (EA)

glomerophyric A term applied to the texture of porphyritic igneous rocks containing closed clusters of equant crystals of the same mineral. (EA)

goal The numerical or nonnumerical objective assigned to performance measure, parameter, or design objective to aid in the planning and direction of work activities.

Gondwana (GEOL) The Late Paleozoic continent of the Southern Hemisphere. It was named for the Gondwana system of India, which has an age range from Carboniferous to Jurassic and contains glacial tillite in its lower part and coal measures higher up. The counterpart of Gondwana in the Northern Hemisphere was Laurasia; the supercontinent from which both were derived was Pangea.

gouge The clay or clay-bearing material in a fault zone. Also crushed rock along a fault slip. (BWIP, EA)

graben An elongated, relatively depressed crustal unit or block that is bounded by faults on its long sides. (BWIP)

granite A medium- to coarse-grained intrusive igneous rock consisting primarily of feldspar and quartz. (BWIP, EA)

gravity survey The systematic measurement of the gravity field of a specified area. (BWIP, EA)

gross alpha The total rate of alpha particle emission from a sample, without regard to energy distribution or source nuclides. (BWIP)

gross beta The total rate of beta particles emitted from a material, without regard to energy distributions or source nuclides. (BWIP)

ground magnetic survey A determination of the magnetic field at the surface of the Earth by means of ground-based instruments. (EA)

groundmass The continuous, fine-grained material between the phenocrysts of a porphyritic igneous rock. May be crystalline, glassy, or both. (BWIP)

ground motion (earthquake) The displacement of the ground due to the passage of elastic waves arising from earthquakes, explosions, seismic shots, and the like. (EA)

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groundwater All subsurface water as distinct from surface water. (10 CFR 960.2)

groundwater flux The rate of groundwater flow per unit area of porous or fractured media measured perpendicular to the direction of flow. (10 CFR 960.2)

groundwater path length The distance from a point where material is introduced into groundwater to the point where the groundwater enters an accessible aquifer or discharges to the water table or surface water. (BWIP)

groundwater recharge rate The rate at which water is added to the zone of saturation (either directly into a formation or indirectly by way of another formation). (BWIP, EA)

groundwater residence time The time that groundwater remains in an aquifer or aquifer system. (BWIP, EA)

groundwater sources Aquifers that have been or could be economically and technologically developed as sources of water in the foreseeable future. (10 CFR 960.2)

groundwater travel time The time required for a unit volume of groundwater to travel between two locations. The travel time is the length of the flow path divided by the velocity, where velocity is the average groundwater flux passing through the cross-sectional area of the geologic medium through which flow occurs, perpendicular to the flow direction, divided by the effective porosity along the flow path. If discrete segments of the flow path have different hydrologic properties, the total travel time will be the sum of the travel times for each discrete segment. (10 CFR 960.2)

grout

(a) (as related to structures) A neat cement, cement mixed with sand, or cement mixed with bentonite or other clay. It is usually injected under pressure into foundations through specially drilled holes for the purpose of sealing off or filling joint seams, fissures, or other openings. (BWIP)

(b) (as used in a repository) A mortar or cement-water-additive mixture used to seal boreholes. In radioactive waste processing it may be combined with liquid waste to provide a matrix for isolation of the waste and to seal the waste from the environment. (BWIP)

guideline A statement of policy or procedure that may include, where appropriate, qualifying, disqualifying, favorable, or potentially adverse conditions as specified in the "guidelines." (10 CFR 960.2)

guidelines Part 960 of Title 10 of the Code of Federal Regulations--General Guidelines for the Recommendation of Sites for the Nuclear Waste Repositories. (10 CFR 960.2)

gypsum A mineral consisting of hydrous calcium sulfate $CaSO_4(2H_2O)$. It is soft and, when pure, white or clear. (BWIP)

half-life Biological half-life; time required for half of an ingested (or inhaled) substance to be eliminated by natural processes. (EA)

halite (MINERO) The mineral rock salt; sodium chloride NaCl. (BWIP)

Hanford Site A 1,500-km^2 (570-mi^2) U.S. Department of Engergy reservation in south-central Washington State near the Columbia River. The nearest city is Richland, Washington. The Hanford Site is not to be confused with the candidate sites or candidate area, as the Hanford Site is the current name of the government-owned preserve previously called the Hanford Reservation. (BWIP)

hanging wall The overlying side of a fault or other structure. (EA)

haploxylon (GEOL) Bisaccate pollen, in which the outline of the sacci in distal-proximal view is more or less continuous with the outline of the body, the sacci appearing more or less crescent-shaped, and the outline of the whole grain presenting generally smooth elipsoidal forms.

headframe The steel or timber frame at the top of a shaft which carries the sheave or pullies for the hoisting rope and serves various other purposes. (BWIP, EA, USBM)

head, hydraulic See hydraulic head.

heat affected zone (HAZ) That portion of the base metal that was not melted during brazing, cutting, or welding, but whose microstructure and properties were altered by the heat of these processes.

heat emission For the purpose of establishing waste package acceptance criteria, the total amount of heat energy dissipated from a radioactive waste package. (BWIP, EA)

heavy metal All uranium, plutonium, or thorium placed into a nuclear reactor. (BWIP, EA)

heterophyllous (GEOL) Having two different kinds of leaves on the same stem.

heulandite A zeolite mineral often occurring in cavities in decomposed basic igneous rocks. (BWIP)

high-level liquid waste The aqueous waste from the first stage solvent extraction in a reprocessing facility and the concentrated wastes from subsequent stages or equivalent wastes from a process not using solvent extraction. (BWIP)

high-level radioactive waste (1) The highly radioactive material resulting from the reprocessing of spent nuclear fuel, including liquid waste produced directly in reprocessing and any solid material derived from such liquid waste that contains fission products in sufficient concentrations, and (2) other highly radioactive material that the NRC, consistent with existing law, determines by rule requires permanent isolation. (10 CFR 960.2)

high-level waste (HLW) facility A facility subject to the licensing and related regulatory authority of the U.S. Nuclear Regulatory Commission pursuant to Sections 202(3) and 202(4) of the Energy Reorganization Act of 1974. (10 CFR 60)

highly populated area Any incorporated place (recognized by the decennial reports of the U.S. Bureau of the Census) of 2,500 or more persons, or any census designated place (as defined and delineated by the Bureau) of 2,500 or more persons, unless it can be demonstrated that any such place has a lower population density than the mean value for the continental United States. Counties or county equivalents, whether incorporated or not, are specifically excluded from the definition of "place" as used herein. (10 CFR 960.2)

hinge line A line connecting points of maximum curvature along a fold; also, the boundary between a tectonically stable region and a region moving upward or downward.

historical seismicity (earthquake) Earthquake activity that occurred during man's recorded history, including those reported before seismographs existed (preinstrumental) and those recorded by seismographs (instrumental). (BWIP, EA)

Holocene An epoch of the Quaternary period, from the end of the Pleistocene to the present time. See geologic time scale. (EA)

horizon (GEOL)

(a) A given definite position or interval in the stratigraphic column. (BWIP, EA)

(b) A specific underground level, attitude, or elevation. (BWIP, EA)

host rock The geologic medium in which the waste is emplaced, specifically the geologic materials that directly encompass and are in close proximity to the underground facility. (10 CFR 960.2)

hot cell Facility with remote-handling capabilities and adequate shielding for handling highly radioactive substances. (BWIP, EA)

Huronian (GEOL) A division of the Proterozoic of the Canadian Shield.

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hyalocrystalline A textural term referring to an igneous rock in which glass groundmass constitutes approximately three-eighths to five-eighths volume proportion of rock. (EA)

hydraulic conductivity The volume of water that will move through a medium in a time under a unit of hydraulic gradient through a unit area measured perpendicular to the direction of flow. (10 CFR 960.2)

hydraulic gradient A change in the static pressure of groundwater, expressed in terms of the height of water above a datum, per unit of distance in a given direction. (10 CFR 960.2)

hydraulic head The height above sea level to which a column of water can be supported by the static pressure at that point. The total hydraulic head is the sum of elevation head, pressure head, and velocity head.

hydraulics An engineering discipline dealing with the statics and dynamics of fluids. (MP)

hydraulic transmissivity See transmissivity.

hydraulic transport The transport of dissolved substances by groundwater. See hydrologic transport. (BWIP)

hydrocarbon resource Petroleum, natural gas, or gas condensate that exists in sufficient quantities to be economically feasible to remove for use.

hydrofracturing A fracture or a system of fractures treated by hydraulic fracturing process.

hydrogen embrittlement (HE) A loss of ductility of metal resulting from absorption of hydrogen.

hydrogeologic unit Any soil or rock unit or subsurface zone that has a distinct influence on the storage or movement of groundwater by virtue of its porosity or permeability. See also geohydrologic unit. (BWIP, EA)

hydrologic regime The distribution, characteristics, and interrelationships of the aqueous components of the geologic environment. (BWIP, EA)

hydrologic modeling The process of using a mathematical representation of a hydrologic system (as embodied in a computer code) to predict the flow of groundwater and the movement of dissolved substances. (BWIP, EA)

hydrologic process Any hydrologic phenomenon that exhibits a continuous change in time, whether slow or rapid. (10 CFR 960.2)

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hydrologic properties Those properties of a rock that govern the entrance of water and the capacity to hold, transmit, and deliver water, such as porosity, effective porosity, specific retention, permeability, and the direction of maximum and minimum permeabilities. (10 CFR 960.2)

hydrologic transport Transport of solutes through a geologic formation due to movement of groundwater. (BWIP, EA)

hydrology The science that treats the occurrence, circulation, distribution, and properties of the waters of the Earth and their reaction with the environment. (EA)

hydrosere Of or pertaining to a sere that develops in an aquatic environment; a hydrarch sere. See geohydrologic.

hydrosphere The waters of the Earth, as distinguished from the rocks (lithosphere), living things (biosphere), and air (atmosphere). (BWIP)

hydrostatic equilibrium The static head is the height above a standard datum (such as sea level) of the surface of a column of water (or other liquid) that can be supported by the static pressure at a given point. When fluid bodies of equal head are connected, the result is a condition where there is no relative movement of liquid between the fluid elements. Such a system is said to be in hydrostatic equilibrium. (BWIP)

hydrostatic pressure The pressure of, or corresponding to, the weight of a column of water at rest. (BWIP, EA)

hydrothermal alteration Alteration of rocks or minerals by the reaction of heated water with preexisting solid phases. (EA)

hydrothermal reactions The reaction of materials under aqueous conditions at elevated temperatures and pressures. A component of hydrothermal test mixtures is usually the host rock, but such mixtures may contain any or all waste package components. (EA)

hypocenter The focus or specific point at which initial rupture occurs in an earthquake. (BWIP, EA)

Hypsithermal A term proposed as a substitute for climatic optimum and thermal maximum. It represents an interval within the Holocene interval when "most of the world entered a period when mean annual temperatures exceeded those of the present." The Hypsithermal was taken to include the Boreal, Atlantic, and Subboreal climatic intervals, or from about 9,000 to 2,500 yr ago.

igneous Formed by volcanic action or intense heat (solidified from an original melt). (BWIP, EA)

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igneous activity The emplacement (intrusion) of molten rock material (magma) into material in the Earth's crust or the expulsion (extrusion) of such material onto the Earth's surface or into its atmosphere or surface water. (10 CFR 960.2)

igneous rock Rock formed by solidification of a molten material that originated within the Earth. (BWIP, EA)

Illinoian Pertaining to the classical third glacial stage of the Pleistocene Epoch in North America, between the Yarmouthian and Sangamonian interglacial stages.

image analysis The quantitative analysis of a specimen, using the optical counterpart of the specimen, produced by the enhanced reflection or refraction of light when focused by an electronic optical system. (EA)

imbricate faulting A zone of closely spaced faults exhibiting a structure of tabular masses that overlap one another as shingles on a roof. (EA)

immobilization Treatment and (or) positioning of nuclear wastes so as to impede the movement of radioactive isotopes. (BWIP, EA)

important to safety Those engineered structures, systems, and components essential to the prevention or mitigation of an accident that could result in a radiation dose to the whole body, or any organ, of 0.5 rem or greater at or beyond the nearest boundary of the unrestricted area at any time until the completion of permanent closure. (10 CFR 60, BWIP)

important to waste isolation Those engineered and natural barriers that are essential to mitigate the transport of emplaced radioactive material, such that the amounts and concentrations of this material entering the accessible environment will be kept within the prescribed limits. (BWIP)

improved-performance plan (as used by the Civilian Radioactive Waste Management Program) A waste management system that includes the monitored retrievable storage (MRS) facility as an integral part. Most or all spent fuel could be shipped directly from reactor sites to an MRS facility. Spent fuel from reactors located close to a repository, but an appreciable distance from the MRS facility, may be shipped directly to the repository. Solidified high-level waste could be shipped directly to the repository or to the MRS facility. (MP)

incident Any deviation from the planned or expected behavior of an activity or operation. Also, a course of events which has or may have a significant programmatic, safety, health, or environmental impact. Significant programmatic impacts include those associated with reliability, cost, schedule, data loss, or questions of data validity or analysis.

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independent assessment An assessment, made outside the normal advocacy chain, of a project's status or condition. (DOE 4700)

independent cost estimate A documented cost estimate that has the express purpose of serving as an analytical tool to validate, cross-check, or analyze estimates developed by proponents of a project. An independent cost estimate also serves as a basis for verifying risk assessments. (DOE 4700)

independent technical review A documented single or multidiscipline review of technical material performed by qualified personnel who are independent of the original work performed and external to the project. See peer review.

Indian tribe

(a) Any Indian tribe, band nation, or other organized group or community of Indians recognized as eligible for the services provided to Indians by the Secretary of the Interior because of their status as Indians, including any Alaska native village, as defined in Section 3(c) of the Alaska Native Claims Settlement Act. (MP)

(b) An Indian tribe as defined in the Indian Self-Determination and Education Assistance Act. (10 CFR 60)

indirect cost A cost that is incurred by an organization for common or joint objectives and cannot be identified specifically with a particular project or activity. (10 CFR 60, DOE 4700)

induration The hardening of rock material by heat, pressure, or the introduction of some cementing material. (MP)

informal review A review performed and conducted by Basalt Waste Isolation Project personnel or participants prior to release or issue of a document, to ensure its adequacy and completeness.

information This term is restricted to facts, data, or knowledge itself, rather than to the medium of its conveyance. (Documents and materials are deemed to convey information and are not considered to be information per se.) (DOE 5635.1)

information needs Parameters grouped by technical discipline. An information need usually feeds one investigation, however, investigations may cover several information needs. Information needs are based on disciplines for the purpose of gathering parameters that address different U.S. Department of Energy issues.

in situ In the natural or original position. The phrase is used in this document to distinguish in-place experiments, rock properties, and so on from those in the laboratory or field. Derived from Latin for "in its original place." (BWIP, EA, MP)

in situ stress The magnitude and state of ground stress in a rock mass. The inherent stress in a rock mass at depth. (BWIP, EA)

in situ tests Tests that are conducted with subject material in its original place (i.e., at the repository site and depth). See also field tests. (BWIP, EA)

inspection Examination or measurement to verify whether or not an item or activity conforms to specified requirements. (BWIP)

instrumental seismicity Earthquakes recorded on a seismograph (an instrument designed to detect and record earthquakes). (BWIP, EA)

intact rock failure envelope The intact rock failure envelope represents the calculated rock strength at various levels of confining stress. (EA)

intensity (earthquake) Measure of the effects of an earthquake on man, on man-built structures, and on the Earth's surface at a particular location. Quantified by a numerical value on the modified Mercalli scale. See magnitude (earthquake), modified Mercalli scale, and Richter scale. (BWIP, EA)

interbed Sedimentary unit occurring between or alternating with sequential basalt flows. (EA)

intercalated Occurring between two rock layers or within a series of layers. (EA)

interflow Occurring between flows, as in interflow zone. (BWIP, EA)

interglacial Pertaining to or formed during the time interval between two successive glacial epochs or between two glacial stages. The term implies both the melting of ice sheets to about their present level, and the maintenance of a warm climate for a sufficient length of time to permit certain vegetational changes to occur.

intergranular Refers to the ophitic texture of an igneous rock in which the augite occurs as an aggregation of grains, not in optical continuity, in the interstices of a network of feldspar laths, which may be diverse, subradial, or subparallel. The interstitial augite forms a relatively small proportion of the rock. (EA)

intergranular corrosion Preferential corrosion at or along the grain boundaries of a metal. Also called intercrystalline corrosion.

interim storage Short-term, temporary storage operations for which (1) surveillance and human controls are provided; and, (2) subsequent action involving treatment, transportation, or final disposition is expected. The time scale encompassed in this definition is typically a few decades. (BWIP, EA)

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interim storage facility A Federally owned and operated system that would provide storage for no more than 1,900 metric tons (2 tons) of spent fuel from civilian reactors whose owners cannot reasonably provide adequate storage capacity on site. (MP)

internal structures As pertains to internal characteristics of basalt flows forming during emplacement and cooling, include flow-top breccias, vesicular zones, pillow zones, and cooling-joint patterns such as in the entablature and colonnade. (EA) NOTE: The phrase "forming during emplacement and cooling" has been deleted from later usages.

intersertal A textural term applied to porphyritic igneous rock in which the groundmass occupies the interstices between unoriented feldspar laths, with the groundmass forming a relatively small proportion of the rock. (EA)

interstade A warmer substage of a glacial stage, marked by a temporary retreat of the ice; "a climatic episode within a glaciation during which a secondary recession or a stillstand of glaciers took place."

interstices Small openings between solid particles in a rock or unconsolidated material; may be voids or pores and often contain groundwater. (BWIP)

interstitial A term referring to the space between particles or grains. (MP)

interstitial compounds Interstitial deposits formed subsequently to the rock formations whose pores they have filled by impregnation. (BWIP, EA)

intracanyon Occurring within a canyon. (EA)

intraflow structures (as pertains to internal characteristics of basalt flows) Flow-top breccias, vesicular zones, pillow zones, and cooling joint patterns (e.g., the entablature, columnar entablature, and colonnade).

intrinsic permeability A measure of the relative ease with which a porous medium transmits a liquid under an existing potential gradient. It is a property of the medium alone and is independent of the nature of the fluid. (BWIP)

intrinsic properties Strength, permeability, and sorption characteristics of rocks. (MP)

intrusive

(a) A molten igneous mass that has penetrated surrounding rock.

(b) The entrance into an area or space by humans or their artifacts. (BWIP)

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inversion An atmospheric condition where a lower layer of cool air is trapped below an upper layer of warm air so that the cooler air cannot rise. Inversions spread air horizontally so that contaminating substances cannot be widely dispersed. (EA)

investigation Applied in Section 8.3 of the Site Characterization Plan to the first major subdivision of a specific program and is normally supported by two or more related studies or activities.

ion An atom or group of atoms that is not electrically neutral but instead carries a positive or negative electric charge. See anion and cation. (EA, MP)

ion exchange A chemical reaction in which mobile ions from a solid are exchanged for like ions in a solution. (EA)

ionizing radiation Any radiation displacing electrons from atoms or molecules, thereby producing ions (e.g., alpha, beta, and gamma radiation). (EA)

irradiated The act or condition of being exposed to radiation (as from a nuclear reactor or particle accelerator). (BWIP)

irradiation Exposure to radiation (as from a nuclear reactor or particle accelerator). (MP)

isokinetic A line in a given surface on a graph connecting points with represent equal wind speed. (BWIP)

isolation (as related to radioactive waste) Inhibiting the transport of radioactive material so that the amounts and concentrations of this material entering the accessible environment will be kept within prescribed limits. (10 CFR 960.2)

isolation barrier (engineered) A barrier designed and emplaced in a geologic repository to prevent or limit contact between nuclear waste and the biosphere for a specified time interval. (BWIP)

isolation barrier (natural) (as related to nuclear waste storage in a geologic repository) The Earth material around the underground disposal rooms; it acts to prevent radioactivity from entering the biosphere. (EA)

isopach A line on a map drawn through points of equal thickness of a designated rock unit. (EA)

isopach map A map that shows the thickness of a geologic unit throughout a geographic area by means of isopach lines at regular intervals. (EA)

isostatic (compensation) The adjustment of the lithosphere of the Earth to maintain equilibrium among units of varying mass and density; excess mass above is balanced by a deficit of density below, and vice versa.

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isotherm A line joining data points on a map or chart having the same temperature. (BWIP, EA)

isotope One of several possible forms of one element having the same number of protons in the nucleus and the same atomic number, but a different number of neutrons and thus a different mass number or atomic weight. (BWIP)

issue

(a) As used by the U.S. Nuclear Regulatory Commission (NRC):

- Licensing issues are technical questions that the NRC staff will address in order to (1) complete the licensing assessment of site suitability and (or) design suitability in terms of 10 CFR 60, Subpart E, and (2) adopt the Environmental Impact Statement (EIS) prepared by the U.S. Department of Energy (DOE). Licensing issues include both performance issues and site issues.

- Performance issues are broad questions common to all sites concerning both the operational and long-term performance of the various components of the overall geologic repository system. These issues are derived directly from the performance objectives of 10 CFR 60, Subpart E.

- Site issues include site specific technical questions about those significant conditions and processes needed to address the performance issues.

(b) As used by the DOE:

- Mission Plan key issues are key issues that are identified in the DOE's Mission Plan (DOE 1985). These key issues are derived directly from the system guidelines in the DOE's siting guidelines (10 CFR 960). The key issues cover four areas: (1) postclosure performance; (2) preclosure radiological safety; (3) environment, socioeconomics, and transportation; and (4) ease and cost of siting, construction, operation, and closure.

- Issues are subordinate to key issues. Collectively, the group of issues under a key issue indicates what questions must be answered to satisfy the key issue. Taken together, the issues provide a conceptual outline to structure the resolution strategies for each key issue. The issues are derived, in part, from the technical quidelines of 10 CFR 960, from the performance objectives and design criteria of 10 CFR 60, and from the requirements of 40 CFR 191.

- Performance issues generally address questions regarding compliance with regulatory requirements that are related to the performance of the mined geologic disposal system. They generally relate directly to the highest level of regulatory requirements to be satisfied or findings that must be made. For example, there are performance issues that correspond to each of the postclosure performance objectives set forth in 10 CFR 60.112. Performance issues identify the information related to design, site characteristics, and performance assessments needed to address the regulatory requirements. Information about performance assessments is addressed directly by the performance issues; information about design and site characteristics is addressed by the design and characterization issues, respectively.

- Design issues address needs for information about the design of the repository, seals, and waste package. Design issues may address design criteria specified in 10 CFR 60.130 through 60.134, preclosure system and technical guidelines in 10 CFR 960.5-1 and 960.5-2, and (or) information required to support resolution of the performance issues. Design issues also identify information about site characteristics that is needed for design purpose.

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issue resolution strategy process The process defined by the U.S. Department of Energy for the systematic identification of technical questions (issues) to be resolved. It includes a description and recommendation of the manner in which work is to be planned for the resolution of these questions.

joint (geologic) A surface of fracture or parting in a rock, without displacement; the surface is often a plane and may occur with parallel joints to form a joint set. (EA)

jointing, columnar See columnar jointing. (BWIP, EA)

Jurassic The second period of the Mesozoic era (after the Triassic and before the Cretaceous), thought to have covered the span of time between 190 and 195 m.y. ago; also, the corresponding system of rocks. It is named after the Jura Mountains between France and Switzerland, in which rocks of this age were first studied.

K_d See distribution coefficient.

K_{eff} (multiplication factor) A measure of the dynamic neutron equilibrium level in fissionable materials, defined by the ratio of the average number of neutrons produced by fission in each generation to the average number of such neutrons in the previous generation. When the multiplication factor is one or greater, a self-sustaining chain reaction is possible. (BWIP)

kelly The rod attached to the top of the drill column in rotary drilling. It passes through the rotary table and is turned by it, but is free to slide. (BWIP)

kinetics
(a) A branch of science that deals with the effects of forces upon the motions of material bodies or with changes in a physical or chemical system. (EA)

(b) Study of systems where chemical composition of energy distribution is changing with time.

kriging An interpolation technique that can provide unbiased estimates of a spatially distributed quantity at points, or in regions, where data are lacking. The kriging algorithm is designed to minimize the error of each estimate. (EA)

laboratory analyses/measurements Determinations of chemical, physical, mechanical, or thermal properties of experimental materials or samples recorded in an accurate, traceable, and reproducible manner. Laboratory analyses/measurements are performed in accordance with documented procedures. For the Basalt Waste Isolation Project these are found in basalt operating procedures or test instructions in supporting documents.

laboratory experiments Tests or test sequences that manipulate experimental materials alone or in combination (e.g., basalts or container, backfill, and seal materials) to determine the effect on their chemical, physical, mechanical, or thermal properties under a variety of test conditions. Laboratory experiments result in experimental data/samples subject to laboratory analysis and measurement.

lacustrine Pertaining to, produced by, or formed in a lake or lakes. (EA)

lahar A type of mudflow composed chiefly of volcaniclastic materials on the flank of a volcano. (EA)

lava Molten material (magma) that pours out on the Earth's surface from volcanoes or fissures in the Earth. (MP)

leachate A solution obtained by leaching (e.g., water that has percolated through soil containing soluble substances and thus contains certain amounts of these substances in solution). (EA)

leaching The dissolution of the soluble constituents of a solid material (e.g., the waste) by the action of percolating water or chemicals. (EA)

leakage Refers to groundwater flow across or through a rock zone of low permeability. (EA)

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Level 1 (in siting) A specific finding on a disqualifying condition as described in Appendix III of the General Siting Guidelines; i.e., "The evidence does not support a finding that the site is disqualified." (10 CFR 960, EA)

Level 2 (in siting) A specific finding on a disqualifying condition as described in Appendix III of the General Siting Guidelines; i.e., "The evidence supports a finding that the site is not disqualified on the basis of that evidence and is not likely to be disqualified." (10 CFR 960, EA)

Level 3 (in siting) A specific finding on a qualifying condition as described in Appendix III of the General Siting Guidelines; i.e., "The available evidence does not support a finding that the site is not likely to meet the qualifying condition." (10 CFR 960, EA)

Level 4 (in siting) A specific finding on a qualifying condition as described in Appendix III of the General Siting Guidelines: i.e., "The evidence supports a finding that the site meets the qualifying condition and is likely to continue to meet the qualifying condition." (EA)

leveline survey A geodetic survey in which changes in elevation are very carefully measured at specific points. (BWIP)

level of effort (LOE) An earned value method used for support-type effort that does not readily lend itself to measurement of discrete accomplishment or does not directly affect schedule. The budgeted cost of work performed is always equal to budgeted cost of work scheduled; therefore, there can be no schedule variance.

license application An application for permits and authorization from responsible Federal, State, and local regulatory agencies to site, construct, operate, and decommission a repository. Such an application is usually accompanied by required documentation showing that the nuclear facility and its safety-related systems, with reasonable assurance, can be operated without undue risk to the health and safety of the public and with adequate provisions for the protection of property and the environment. (EA)

license application design. The design that presents the resolution of design and licensing issues identified and assessed in earlier design phases and develops the design of the items necessary to demonstrate compliance with the design requirements and performance objectives of 10 CFR 60. Design requirements resulting from safety and reliability analyses will be integrated in this design to support the safety analysis report and the license application.

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licensing The process of obtaining the permits and authorizations from responsible Federal, State, and local regulatory agencies required to site, construct, operate, and decommission a repository. Includes preparing required documentation, submitting it to the appropriate agencies, responding to agency requests for additional information, and testifying as necessary at public hearings. Within the licensing framework, as defined in statutory requirements, approved permits or licenses must be available prior to the commencement of the activity involved. (BWIP, EA)

licensing assessment An assessment of whether a license application complies with all of the requirements that it purports to meet. For this program, it is the sum of the individual findings for each of the requirements of 10 CFR 60.

licensing strategy The methodology by which the project intends to determine compliance with all applicable regulatory criteria (i.e., 10 CFR 20, 10 CFR 60, 10 CFR 960, 40 CFR 191) and concerns of program participants (i.e., State, Indians, U.S. Geological Survey) that require reasonable assurance.

Licensing Topical Report A report issued by the Civilian Radioactive Waste Management Program and submitted to U.S. Nuclear Regulatory Commission for review to support licensing activities, prior to issuance of a license application. (BWIP)

life cycle cost (LCC) The sum total of the direct, indirect, recurring, nonrecurring, and other related costs incurred or estimated to be incurred in the design, development, production, operation, maintenance, support, and final disposition of a major system over its anticipated useful life span. Where system or project planning anticipates use of existing sites or facilities, restoration and refurbishment costs should be included. (DOE 4700)

ligand The anion or molecule with which a cation forms a complex. (EA)

lignite A brownish-black coal in which the alteration of vegetable material has proceeded further than in peat, but not so far as subbituminous coal. (EA)

likely Possessing or displaying the qualities, characteristics, or attributes that provide a reasonable basis for confidence that what is expected indeed exists or will occur. (10 CFR 960.2)

likely consequence of failure The reasonable estimate of a result caused by a scenario postulating a design event and a series of system or component failures.

limits (operating) Capacity, temperature, pressure, volume, stress, or concentration limits established to preclude hazards to personnel or equipment damage and to optimize operations. (BWIP)

lineament A linear topographic feature of regional extent that is believed to reflect crustal structure. Examples are fault lines, aligned volcanoes, and straight stream courses. (EA)

liquefaction The sudden large decrease in the shearing resistance of a cohesionless soil, caused by a collapse of the structure by shock or strain and associated with a sudden, but temporary, increase of the pore fluid pressure. It involves a temporary transformation of the material into a fluid mass. (BWIP)

liquid breach scenario A postulated sequence of events in which radionuclides are carried by groundwater and released into the environment of man. (BWIP)

lithification The conversion of unconsolidated sediment into solid rock by processes such as compaction, cementation, and crystallization. (BWIP)

lithology The study of rocks. The description of rock characteristics such as structure, color, mineral composition, grain size, and arrangement of its component parts. (BWIP, EA)

lithologic sample Basalt core; sediment core; unconsolidated well sediments; chips derived from rotary, cable tool, or any other drilling method; surface material collected in the field (field samples); or samples derived from any of the above. (BWIP)

lithophysae Hollow, bubble-like structures composed of concentric shells of finely crystalline alkali feldspar, quartz, and other materials. (MP)

lithosphere The solid part of the Earth, including any groundwater contained within it. (10 CFR 960.2)

lithostatic pressure The confining pressure at depth in the crust of the Earth due to the weight of the overlying rocks. (BWIP, EA)

loess A homogeneous unstratified deposit of windblown dust composed predominantly of sand and silt. (EA)

long-lived isotope A radioactive nuclide that decays at such a slow rate that a quantity of it will exist for an extended period; usually radionuclides whose half-life is greater than 3 yr. For the purposes of the repository, any radionuclide with a half-life of greater than 100 yr. NOTE: The 100-yr period is not used by the U.S. Environmental Protection Agency. (BWIP)

low-heat waste Liquid radioactive waste that does not generate sufficient fission product decay heat to boil or self-concentrate. (BWIP)

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low-level (radioactive) waste (LLW) Radioactive material that (1) is not high-level waste, spent fuel, transuranic waste, or byproduct material as defined in Section 11e(2) of the Atomic Energy Act of 1954; and (2) the U.S. Nuclear Regulatory Commission, consistent with existing law, classifies as low-level radioactive waste. (MP)

low-level transuranic waste Transuranic waste packages whose surface dose rate is sufficiently low to permit direct-contact handling; also referred to as contact-handled transuranic waste. (BWIP, EA)

macroearthquake For the purpose of this study, an earthquake that is felt by people or an earthquake having a magnitude of 3 or greater on the Richter scale. (BWIP, EA)

macroseismic region The area in which an earthquake is felt by the inhabitants. (BWIP)

magma Molten material that originates from the lower crust and upper mantle from which igneous rocks are thought to have been derived through solidification and related processes. (MP)

magnetic survey A survey made with a magnetometer, on the ground or in the air, that reveals local variations in magnetic field intensity. (EA)

magnetometer An instrument that measures the Earth's field or the magnetic field of a particular rock. See magnetic survey. (EA)

magnetostratigraphy Stratigraphy based on paleomagnetic signatures (remanent magnetization). (EA)

magnetotelluric method A geophysical surveying method that measures the natural electric and magnetic fields of the Earth. (BWIP, EA)

magnitude (earthquake) The measure of the strength of an earthquake; related to the energy released in the form of seismic waves. Magnitude is quantified by numerical value on the Richter scale. See intensity (earthquake), modified Mercalli scale, and Richter scale. (BWIP, EA)

man-rem A unit used in health physics to compare the effects of different amounts of radiation on groups of people. It is obtained by multiplying the average dose equivalent to a given organ or tissue (measured in rems) by the number of persons in that population. (EA)

material A substance or combination of substances forming components, parts, pieces, and equipment items (intended to include machinery, casting, liquids, formed steel shapes, aggregates, and cement). (BWIP)

Material Review Board (MRB) A selected panel of Basalt Waste Isolation Project managers, technical personnel, and quality assurance (QA) representatives qualified by their knowledge and experience to evaluate and disposition nonconformances. A QA representative is appointed MRB chairperson by the QA manager.

mathematical model A mathematical representation of a process, component, or system.

matrix, waste The material in which radioactive nuclear waste is encapsulated. (BWIP)

maximum consequence of failure The most serious performance consequence resulting from any unanticipated event.

maximum credible earthquake The strongest earthquake that, considering the earthquake history and the tectonic setting of a place, could be reasonably expected to occur during the preclosure and postclosure phases of a repository. (BWIP, EA)

maximum permissible concentration (MPC) The average concentration of a radionuclide in air or water to which a worker or member of the general population may be continuously exposed, thus limiting external and (or) internal doses to within an established standard of radiation dose limits. (BWIP, EA)

may Denotes permission but not a requirement. See shall; shall, should, may; and should.

member of the public Any individual who is not engaged in operations involving the management, storage, and disposal of radioactive waste. A worker so engaged is a member of the public except when on duty at the geologic-repository operations area. (10 CFR 960.2)

Mercalli intensity See modified Mercalli scale. (EA)

meridional Pertaining to a movement of direction between the poles of an object (e.g., the Earth's north-south water or air circulation patterns).

mesostasis The last-formed interstitial material, either glassy or aphanitic, of an igneous rock. (EA)

Mesophytic A paleobotanic division of geologic time, signifying the time between the first occurrence of gymnosperms and that of angiosperms.

Mesozoic An era of geologic time, from the end of the Paleozoic to the beginning of the Cenozoic. See geologic time scale. (EA)

Messinian European stage: uppermost Miocene (above Tortonian, below Zanclean).

metallography The study of the structure of metals, especially through use of the microscope. (BWIP)

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metamorphic rock Includes all those rocks that have formed in the solid state in response to pronounced changes of temperature, pressure, and chemical environment, which take place, in general, below the surface zones of weathering and cementation. (BWIP, EA)

metamorphism The mineralogic, chemical, and structural adjustment of solid rocks to physical and chemical conditions imposed at depth below the surface zones of weathering and cementation conditions, that differ from those under which the rocks originated. (EA)

metasediments Sedimentary rocks altered by the effects of heat or pressure or both. (EA)

metavolcanic Volcanic rocks altered by the effects of heat or pressure or both. (EA)

metric tons uranium That measure of weight equivalent to 1 metric ton (2,204.6 lb) of uranium and other fissile and fertile material that are loaded into a reactor core as fresh fuel. (MP)

microearthquake An earthquake that is not felt or has a magnitude of less than 3 on the Richter scale. (BWIP, EA)

microseismic region The area in which an earthquake is recorded by instruments only. (BWIP, EA)

microsilica shotcrete This type of shotcrete contains more finely ground silica sand than ordinary shotcrete. (EA)

migration

(a) The transfer of computer systems from one computer to another. This usually requires program modification so that the recipient computer can accommodate the transferred software. (IRM)

(b) (as related to fluids) The movement of oil, gas, or water through porous and permeable rock. Parallel (longitudinal) migration is movement across the bedding planes.

(c) (as related to seismic data) Plotting of seismic reflection-time information to allow for the fact that reflecting points do not lie vertically beneath the point of observation. Involves both reflector dip and variation of velocity. Often neglects effects perpendicular to the seismic line. (BWIP)

millirem (mrem) A unit of dose of ionizing radiation equal to 1/1,000 rem. See roentgen equivalent man. (BWIP)

mined geologic disposal system A system, requiring licensing by the NRC, that is used for the disposal of high-level radioactive waste in excavated geologic media. It is synonymous with geologic repository.

mineralogy The study of minerals, including their formation, occurrence, properties, composition, and classification. (MP)

mineral resource Metallic and nonmetallic ores that exist in sufficient quantities to be economically feasible to remove the resources for use. (BWIP)

mining
(a) (as related to mining engineering) The technique of mineral discovery and exploitation. NOTE: This definition and related exploration and exploitation activities (e.g., oil drilling, water drilling) are considered in postclosure analyses.

(b) (as related to waste disposal) The excavation of rock (e.g., digging the subsurface portion of the repository). (BWIP)

Miocene An epoch of geologic time within the upper Tertiary Period, after the Oligocene and before the Pliocene. See geologic time scale. (EA)

missile Any object flying through the air with sufficient mass and velocity to present a significant hazard to persons or structures. (EA)

mitigation (1) Avoiding the impact altogether by not taking a certain action or parts of an action; (2) minimizing impacts by limiting the degree or magnitude of the action and its implementation; (3) rectifying the impact by repairing, rehabilitating, or restoring the affected environment; (4) reducing or eliminating the impact over time by preservation and maintenance operations during the life of the action; (5) compensating for the impact by replacing or providing substitute resources or environments. (10 CFR 960.2)

mixed oxide fuel A nuclear fuel, usually for breeder reactors, composed of uranium and plutonium oxides. (BWIP)

modal analysis The analysis of the actual mineral composition of a rock, usually expressed in weight or volume percentages. (EA)

model A conceptual description and the associated mathematical representation of a system, subsystem, component, or condition that is used to predict changes from a baseline state as a function of internal and (or) external stimuli and as a function of time and space. (10 CFR 960.2)

modified Mercalli scale An earthquake-intensity scale having 12 divisions ranging from I (not felt by people) to XII (damage nearly total). Commonly abbreviated MM. See magnitude (earthquake) and intensity (earthquake). (BWIP, EA)

monitored retrievable storage (MRS) A concept for storing waste or spent fuel for long periods. The waste and spent fuel would be continuously monitored and would be stored in such a way that it could be retrieved, at a later date, and sent to a repository. (MP)

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monitoring Routine measuring of the quantity and type of discharges or migration of radioactive waste from a waste management facility, or measuring changes in physical, chemical, or biological characteristics of the site and the surrounding site area. (BWIP, EA)

monocline A downward flexure in otherwise horizontal strata without any corresponding upfold to form a syncline or anticline. Generally a large feature of gentle dip. (BWIP, EA)

moraine A mound, ridge, or other distinct accumulation of unsorted, unstratified rock material left at the margins of a retreating glacier. (EA)

muck

(a) (noun) Broken rock or ore that results from excavation during mining. (EA)

(b) (verb) To load broken rock. (BWIP)

multiple barrier system Concept of using the waste form, the container (canister), the overpack, the emplacement medium, and surrounding geologic media as multiple barriers to isolate the waste from the biosphere. A multibarrier system is a system of barriers, operating independently or relatively independently, that acts to contain and (or) isolate nuclear waste. (BWIP, EA)

MWd/MTU Megawatt days per metric ton of uranium. A unit used for expressing burnup of fuel in a reactor; specifically, the number of megawatt days of heat output per metric ton of uranium in the reactor fuel. (BWIP)

natural barrier The repository host rock and surrounding geologic structures and formations. The natural barriers extend from the engineered barriers to the accessible environment. (DOE 1986b)

natural gamma log A radioactivity log obtained by recording the natural radioactivity of the rocks traversed in a borehole or well and expressed by measuring the intensity of naturally emitted gamma rays and plotting the data as a function of depth. (EA)

natural system The geologic setting that consists of (1) a host rock suitable for repository construction and waste emplacement and (2) the surrounding rock formations. It will include natural barriers that provide containment and isolation by limiting radionuclide transport through the geohydrologic environment to the biosphere, and provide conditions that will minimize the potential for human interference in the future. (MP)

Near-Surface Test Facility (NSTF) A full-scale demonstration facility located in Gable Mountain on the Hanford Site that was constructed to examine how basalt is affected by heat and radiation-induced stresses from the emplacement of nuclear waste. (EA)

Near-Surface Test Facility (NSTF) Operating Procedures Written step-by-step instructions that provide for safe, efficient, and effective performance of specific tasks associated with the operation and test of the NSTF and its support systems.

The NSTF operating procedures are developed and prepared by NSTF operations personnel from test plans submitted by the testing organization. These operating procedures are submitted to Operating Document Control for release after all approvals are obtained.

Neogene An interval of time incorporating the Miocene and Pliocene of the Tertiary period; the later Tertiary. When the Tertiary is designated as an era, then the Neogene, together with the Paleogene, may be considered to be its two periods. See geologic time scale.

neoglaciation The readvance of mountain glaciers during a Little Ice Age interval of the late Holocene.

neutron A particle existing in or emitted from the atomic nucleus; it is electrically neutral and has a mass approximately equal to that of a stable hydrogen atom. (BWIP)

neutron flux A measure of the number of neutrons crossing a unit space in a unit of time, usually expressed in units of neutrons per square centimeter per second. (BWIP)

neutron log A radioactivity log that measures the intensity of radiation (neutrons and gamma rays) artificially produced when the rocks around a borehole or well are bombarded by neutrons from a synthetic source. (EA)

neutron probe A probe that measures the intensity of radiation (neutrons and gamma rays) artificially produced when rocks around a borehole are bombarded by neutrons from a synthetic source. The results are recorded on a neutron log. (EA)

Nevada Test Site (NTS) An area in Clark and Nye Counties in southern Nevada dedicated to the underground testing of nuclear weapons. (EA)

Newtonian fluid A simple fluid in which the state of stress at any point is proportional to the time rate of strain at that point; the proportionality factor is the viscosity coefficient. (BWIP)

nodal zone An area at which the predominant direction of the littoral drift changes. (BWIP)

nonconformity An unconformity in which stratified rocks above the surface rest on unstratified older rocks. (EA)

nondestructive examination/testing The method(s) used to detect external, internal, and (or) concealed defects in materials using techniques that do not impair or destroy items being tested.

nondestructive testing (NDT) Testing methods that do not involve damaging or destroying the test sample (e.g., radiography, ultrasonic, magnetic particle, liquid penetrant, and leak testing). (BWIP)

normal fault A fault in which one side (the hanging wall) appears to have moved downward relative to the other (footwall). The angle of the fault is usually 45° to 90°. (EA)

normalization The decomposition of more complex data structures according to a set of dependency rules, designed to give simpler, more stable structures. (IRM)

nuclear materials Source, byproduct, and special nuclear materials, and waste and scrap contaminated by these materials. (BWIP)

nuclear reactor A device in which a fission chain reaction can be initiated, maintained, and controlled. (MP)

nuclear waste management The planning, execution, and surveillance of essential functions related to the control of radioactive and nonradioactive waste, including treatment, solidification, temporary or long-term storage, surveillance, and isolation. (MP)

nuclide A collective term for all atoms that have the same atomic number and same atomic weight; when radioactive, usually prefixed with "radio." (BWIP)

nuclide inventory (radionuclide inventory) A list of the kinds and amounts of radionuclides in a container or a source. Amounts are usually expressed in activity units (e.g., curies or curies per unit volume). (BWIP)

numerical method A procedure for solving a problem primarily by a sequence of arithmetic operations. (NRC 1983)

numerical model A representation of a process or system using numerical methods. (NRC 1983)

objective An end result of an effort whose attainment can be determined by measurement or fact. Specifically, those items identified in the siting process that are to be addressed for meeting the overall goal (e.g., maximizing public health and safety). (BWIP)

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Oligocene An epoch of the early Tertiary period, after the Eocene and before the Miocene; also, the corresponding worldwide series of rocks. It is considered to be a period when the Tertiary is designated as an era. See also Table A-2 (appendix).

open-circuit potential The potential of an electrode measured with respect to a reference electrode or another electrode when no current flows to or from it. See corrosion potential.

operating basis earthquake (OBE) That earthquake which, considering the regional and local geology and seismology and specific characteristics of local subsurface material, could reasonably be expected to affect the plant site during the operating life of the plant. It is that earthquake that produces the vibratory ground motion for which those features of the repository necessary for continued operation without undue risk to the health and safety of the public are designed to remain functional. See safe shutdown earthquake. (BWIP, EA)

operational date (as related to production plant) The date when operations personnel introduce feed materials into the process equipment with the intent to produce the design plant product (excludes functional testing). (DOE 4700)

operational phase The period of time from the receipt of the first waste at the site (i.e., operating license) to closure and decommissioning. (EA)

ophitic texture Said of the texture of an igneous rock in which lath-shaped plagioclase crystals are partially or completely included in pyroxene crystals, typically augite. (EA)

order of magnitude A factor of ten. When a measurement is made with a result such as 3×10^7, the exponent of 10 (here 7) is the order of magnitude of that measurement. To say that this result is known to within an order of magnitude is to say that the true value lies between (in this example) 3×10^6 and 3×10^8. (BWIP)

Ordovician The second earliest period of the Paleozoic era (after the Cambrian and before the Silurian), thought to have covered the span of time between 500 and 400 m.y. ago; also the corresponding system of rocks.

orogenic belt A linear region that has undergone folding or other deformation during the orogenic cycle. Also known as gold belt; orogen; orogene. (BWIP)

orogeny The process by which structures within fold belt mountainous areas were formed, including thrusting, folding and faulting.

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orographic Said of the precipitation that results when moisture-laden air encounters a high barrier and is forced to rise over it, such as the precipitation of the windward slopes of a mountain range facing a steady wind from a warm ocean. Also, said of the lifting of an air current caused by its passage up and over a mountain.

outcrop A part of a body of rock formation that appears bare and exposed at the surface of the ground. Also referred to as an exposure. (BWIP, EA)

outwash Sorted and stratified rock material deposited by proglacial meltwater streams. (EA)

overall goal A formal statement of the overall goal of the study (i.e., identifying acceptable sites for a nuclear waste repository). (BWIP)

overburden Loose soil, sand, gravel, or other material that lies above the bedrock. The term should not be used without specific definition. Also called burden, cover, drift, mantle, surface. See regolith.

overcoring test

(a) (as related to retrieval) A process for removing waste from its burial in basalt by extracting a cylinder of rock that surrounds and contains the waste.

(b) (as related to rock mechanics) A method of measuring in situ stress. The method involves installation of multidirectional strain recording devices in small boreholes. A larger diameter borehole (overcore) is then advanced concentrically past the strain measuring sensor. The resultant strain relief is then recorded.

overpack A material envelope surrounding a containerized waste form in which the specific canister is not in compliance with the acceptance specifications of the repository, but the entire container will be in compliance when housed within the envelope provided by the overpack. The overpack is not intended for routine application. (EA)

overthrust A low-angle thrust fault of a large scale, with displacement generally measured in kilometers. (EA)

oxidation

(a) The process of combining with oxygen or other oxidant through loss of electrons by a constituent of a chemical reaction.

(b) (as related to metals) The corrosion of a metal that is exposed to an oxidizing gas at elevated temperatures. See reduction (chemical).

oxidize To combine oxygen with some substance, or to raise the valence state of a substance by removing electrons from it. (BWIP)

packer A device used in drilled holes to isolate one part of a borehole from another to carry out studies (e.g., hydrologic) or particular formations or parts thereof. (BWIP, EA)

packer-injection tests A variety of tests whereby a liquid (usually water) or gas is injected into a "sealed-off" or isolated portion of a borehole or well to obtain data on such things as formation permeability and fracture flow parameters of rocks. (EA)

packing The material that is placed in the waste emplacement hole in the annular space between a canister or overpack (if one is present) and the host rock. The packing is a component of the waste package that serves to control the release of radionuclides from the waste package by sealing against water, modifying the water chemistry, sorbing or retarding the transport of radionuclides, or by establishing other improvements in environmental parameters. (An example is a mixture of bentonite clay and crushed rock placed in the annulus between the overpack and host rock.) (EA)

palagonite A hydrated basaltic glass commonly formed when molten basalt that entered water has become weathered; indicative of an aqueous environment, often associated with pillow lava. (BWIP, EA)

paleo A combining form denoting the attribute of great age or remoteness in the past. (BWIP, EA)

Paleocene An epoch of the early Tertiary period, after the Gulfian of the Cretaceous period and before the Eocene; also the corresponding worldwide series of rocks.

paleoclimate The climate of the geologic past. (EA)

paleomagnetism The study of the natural remanent magnetization to determine the intensity and direction of the Earth's magnetic field in the geologic past. (EA)

paleontology The study of life in the geologic past, based on fossilized plant and animal remains. (EA)

paleosalinity The salinity of a body of water in the geological past, as evaluated on the basis of chemical analyses of sediment or formation water.

Paleozoic One of the eras of geologic time, following the Precambrian Era and preceding the Mesozoic Era. It includes the Cambrian, Ordovician, Silurian, Devonian, Mississippian, Pennsylvanian, and Permian Periods. See geologic time scale, Table A-2. (BWIP)

paludal Pertaining to a marsh or swamp. (EA)

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palynology The study of spores, pollen, and micro-organisms that occur in sediments. (EA)

panel A collection of underground rooms connected by a common access and common ventilation corridors. (EA)

Paradox Basin A 25,900-km^2 (10,000-mi^2) area in southeastern Utah and southwestern Colorado underlain by bedded salt and a series of salt-core anticlines. (BWIP, EA)

paragenesis A general term for the order of formation of associated minerals in time succession, one after another. To study the paragenesis is to trace out in a rock or vein the succession in which the minerals developed. (EA)

parameters

(a) (Performance) Those quantities identified in the issue resolution strategies that will be used directly in the resolution of the performance and design issues. These parameters are those to be used directly in the evaluation of performance measures developed in the issue resolution strategies. Performance parameters include any of the input parameters for performance assessment calculations or any of these in the design basis for the analysis of the engineered systems.

(b) (Supporting) Those quantities that are to be evaluated in the investigations to be conducted during the site characterization program. Characterization parameters include information useful in the determination of performance parameter values. For example, supporting parameters describing recharge and groundwater composition may be used in conjunction with geohydrologic conceptual models to infer values for performance parameters such as the hydraulic head distribution.

parasitic anticline An anticlinal fold occurring on one of the flanks of a large anticline. (EA)

parent A radionuclide that upon disintegration yields a specified nuclide, the daughter, either directly or as a later member of a radioactive series. (BWIP)

particulate

(a) Finely divided particles, suspended in a gaseous medium, such as dust in the air. (EA)

(b) (as related to environmental sciences) A particle(s) retained by a 0.45-μm filter. (BWIP)

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partition To separate one (or more) element(s) from one (or more) other element(s). Examples include the separation of uranium and plutonium from each other, the separation of actinides and fission products in the waste, and the separation of one fission product from the other fission products. (BWIP)

Pasco Basin A structural and topographic basin within the western Columbia Plateau. The Hanford Site and reference repository location are located within the Pasco Basin. See Figure A-2 (appendix). (EA)

Pasquill stability category Relates atmospheric stability to the dispersion of an effluent plume. These categories range from extremely unstable (a plume will disperse rapidly) to extremely stable (a plume will not appreciably disperse).

passivation A reduction of the anodic reaction rate of an electrode involved in corrosion.

pathway (as related to waste management) Possible or potential routes by which wastes might reach the accessible environment. (BWIP, EA)

peer One that is of equal standing with another in knowledge, education, training, or experience for a given discipline.

peer review A documented critical review (as decribed in the NRC QA Review Plan, Appendix A, Section 3.8 (NRC 1984)) performed by personnel who are independent of those who performed the work but who have technical expertise at least equivalent to those who performed the original work. Peer reviews are in-depth, critical reviews and evaluations of documents, material, or data that require interpretation or judgment to verify or validate assumptions, plans, results, or conclusions or when the conculsions, material, or data contained in a report go beyond the existing state of the art. (BWIP)

peer reviewer A person, committee, or team who is qualified to evaluate the data, reports, etc., requiring review. Several peer reviewers may be necessary to review material when no one reviewer is qualified to evaluate all the material in a unit.

penecontemporaneous Said of a geologic process, or resultant structure or mineral, occurring immediately after deposition but before consolidation of the enclosing rock. (EA)

perched groundwater Unconfined groundwater separated from an underlying body of groundwater by an unsaturated zone. Its water table is a perched water table. Perched groundwater is held up by a perching bed whose permeability is so low that water percolating downward through it is not able to bring water in the underlying unsaturated zone above atmospheric pressure. (10 CFR 960.2)

percolate (HYD) The passage of a liquid through a porous substance. The movement of water, under hydrostatic pressure developed naturally underground, through the interstices and pores of the rock or soil (i.e., the slow seepage of water through soil or porous deposits). (BWIP, EA)

performance allocation

(a) Assignment of performance objectives, including probability, to the system, subsystem, or components, or to individual parameters that characterize elements of the system. (BWIP)

(b) A part of the process for developing strategies for the resolution of issues, used to guide the site-characterization program.

performance assessment Any analysis that predicts the behavior of a system or system component under a given set of constant and/or transient conditions. Performance assessments will include estimates of the effects of uncertainties in data and modeling. (10 CFR 960.2)

performance confirmation The program of tests, experiments, and analyses which is conducted to evaluate the accuracy and adequacy of the information used to determine with reasonable assurance that the performance objectives for the period after permanent closure will be met. (10 CFR 60.2)

performance criteria Statements of how well a system or subsystem must perform the required functions and in some cases the means for assessing this performance. (DOE 1986b)

performance criterion A criterion establishing qualitative, operational, safety, or environmental limits. (BWIP, EA)

performance evaluation (as used programmatically) An iterative process, using peer review, designed to determine whether individual pieces of work within a project satisfy the project criteria. It is the process that serves as a management tool to determine whether a study-analysis experimental sequence provides necessary and sufficient information to the project to allow management to say that the work in that area is complete. (BWIP)

performance measure A statement of a measurable or derived quantity defined for a given system component that serves as part of the basis for evaluating the performance of the system component. For example, a performance measure for shaft seals may be radionuclides released to the accessible environment through shaft seals.

performance objective or standard The predetermined objective or specification used to evaluate the acceptability of each system, structure, or component in a performance calculation. Different performance standards may be appropriate for preclosure and postclosure periods.

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periglacial Pertaining to the areas, conditions, processes, and deposits marginal to an ice sheet or glacier. (BWIP, EA)

permanent closure Synonymous with closure (repository).

permeability The capacity of a medium such as rock, sediment, or soil to transmit groundwater. Permeability depends on the size and shape of the pores in the medium and the manner in which the pores are interconnected. (EA)

permeability (permeable) (K) The capacity of a material or rock for transmitting a fluid under a hydraulic gradient. It is approximately equivalent to hydraulic conductivity. See hydraulic gradient. (SCP, BWIP) NOTE: This term is equivalent to hydraulic conductivity under saturated conditions.

Permian The last period of the Paleozoic era (after the Pennsylvanian), thought to have covered the span of time between 280 and 225 m.y. ago; also, the corresponding system of rocks. The Permian is sometimes considered part of the Carboniferous, or is divided between the Carboniferous and Triassic. It is named after the province of Perm, Union of Soviet Socialist Republic (U.S.S.R), where rocks of this age were first studied.

petrocalcic A diagnostic subsurface soil horizon that is characterized by an induration with calcium carbonate. (EA)

petrography The branch of geology that deals with the description and systematic classification of rocks, especially igneous and metamorphic rocks, and especially by the microscopic examination of thin sections. (EA)

petrology That branch of geology dealing with the origin, occurrence, structure, and history of rocks. (EA, MP)

pH A measure of the acidity or alkalinity of a solution. (EA)

phaneritic A textural term pertaining to crystals or grains in igneous rocks that are visible to the unaided eye; as opposed to aphanitic. (BWIP, EA)

Phanerozoic That part of geologic time represented by rocks in which the evidence of life is abundant (i.e., Cambrian and later time).

phenocryst A textural term applied to any relatively large, conspicuous crystal in an igneous rock. (EA)

photolineament A lineament observed in remote sensing imagery that is a simple or composite feature of natural origin whose parts are aligned in a rectilinear to slightly curvilinear relationship, and which differs distinctly from the patterns of adjacent features.

phreatic water Pertaining to all groundwater in the zone of saturation. See saturated zone. (BWIP)

pH value The negative $\log_{10}$ of the hydrogen ion activity in a solution; a measure of the acidity or basicity of a solution. (MP)

physical An adjective, contrasted with logical, that refers to the form in which data or systems exist in reality. Data are often converted by software from the form in which they are physically stored to a form in which a user or programmer perceives them. (IRM)

physiography The descriptive study of land forms as opposed to geomorphology, which is the interpretive study of land forms. (EA)

piezometer An instrument for measuring the change of pressure of a material subjected to hydrostatic pressure. (MP)

piezometric An imaginary surface that coincides everywhere with the static level of the water in the aquifer. See also potentiometric surface. (BWIP)

piezometric surface A contoured, mapped surface that coincides everywhere with the static level of the water in an aquifer. See also potentiometric surface. (EA)

pillow lava Basaltic material congealed in rounded masses, indicative of subaqueous flows or eruptions, occurring mostly in basalts. (BWIP, EA)

pintle A pin on the top of a waste canister designed to mate with the canister hoisting mechanism. (BWIP)

pitting Localized corrosion resulting in surface defects. (BWIP)

plagioclase An isomorphous series of (solid solution) triclinic feldspar minerals that form the group of common rock-forming minerals; the silicates of varying mixtures of sodium, calcium, and aluminum, ranging from albite, $NaAlSi_3O_8$, to anorthite, $CaAl_2Si_2O_8$. (BWIP, EA)

planning estimates Estimates developed for each project at the time of project identification. Since these estimates are developed prior to conceptual design, they are the order of magnitude only and have the least amount of accuracy and lowest confidence level. Care should be exercised in these estimates to ensure that the order of magnitude is correct, since a tendency exists to avoid changing this estimate, particularly upward, once the estimate is established. (DOE 4700)

planning package A logical aggregation of work within a cost account, normally far-term effort that can be identified and budgeted in early baseline planning but cannot be planned in the detail required for a work package. It is further broken down into one or more work packages as the necessary information becomes available, or at least 3 mo prior to the scheduled start date. This process is often referred to as the rolling wave concept.

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plant The equipment, piping, structures, buildings, and property that comprise an installation or facility. (BWIP, QA3)

plant and capital equipment (PACE) Funds designated by the U.S. Department of Energy for expenditures for construction, additions, and equipment with a long-life expectancy.

plastic flow Rheology phenomenon in which flowing behavior of the material occurs after the applied stress reaches a critical (yield) value. (BWIP)

plate bearing test A procedure performed in small tunnels or adits to measure the deformation characteristics of a rock mass. Typically two areas, each generally on the order of 1 m (3 ft) in diameter, are loaded simultaneously using hydraulic jacks positioned across the tunnel. Rock mass deformations are measured in boreholes behind each area and across the tunnel. (EA)

Pleistocene The first epoch before the Holocene (or present time) of the Quaternary Period. See geologic time scale. (BWIP, EA)

Pliocene The latest epoch of geologic time within the Tertiary period, preceded by the Miocene epoch, and followed by the Pleistocene epoch. See geologic time scale. (EA)

plug

(a) The vertical pipe-like magmatic body representing the conduit of a former volcanic vent.

(b) A crater filling of lava, the surrounding material of which has been removed by erosion.

(c) A mass of clay, sand, or other sediment filling the part of a steam channel abandoned by the formation of a cutoff.

plug (shaft or borehole) A watertight seal in a shaft formed by removing the lining and inserting a concrete and (or) metal dam, or by placing a plug of clay over ordinary debris used to fill the shaft up to the location of the plug.

pluvial (as related to rain or precipitation) Describes a climate with relatively high amounts of precipitation. (MP)

Poisson's ratio The absolute value of the ratio of the transverse strain to the corresponding axial strain, in a body subjected to uniaxial stress, usually applied to elastic conditions. (BWIP)

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polarization resistance The slope (dE/di) at the corrosion potential of a potential (E)-current density (i) curve. Also used to describe the method of measuring corrosion rates using this slope.

population center A densely populated area of 25,000 or more inhabitants. (EA)

population dose The sum of the radiation doses received by the individual members of a population exposed to a particular source or event. It is expressed in units of man-rem. (EA)

pore (as applied to stone, soil, etc.) Any small, open space; generally one that admits the passage or absorption of liquid within the rock or soil. (BWIP, EA)

porosity The ratio of the total volume of interstices in a rock or soil to its total volume, usually expressed in percentage. (EA, MP)

porosity log A determination of pore volume per unit volume of formation made from a sonic log, density log, neutron log, or resistivity log. (EA)

porphyritic The texture of igneous rocks having larger crystals (phenocrysts) set in a finer groundmass of small crystals or glass or both. (BWIP)

postclosure The period of time after the closure of the geologic repository. (10 CFR 960.2)

potentially acceptable site Any site at which, after geologic studies and field mapping but before detailed geologic data gathering, the DOE undertakes preliminary drilling and geophysical testing for the definition of site location. (10 CFR 960.2)

potentially adverse condition A condition that is presumed to detract from expected system performance, but further evaluation, additional data, or the identification of compensating or mitigating factors may indicate that its effect on the expected system performance is acceptable. (10 CFR 960.2)

potential-pH diagram (also known as Pourbaix diagram) A graphic method of representing the regions of thermodynamic stability of species for metal-electrolyte systems.

potentiometric Said of, or relating to, the hydrostatic pressure level of groundwater. (MP)

potentiometric surface The surface to which the water from a given aquifer will rise by hydrostatic pressure. It is usually represented as a contour map, each point in which tells how high the water would rise in a well tapping that aquifer at that point. See also piezometric surface. (EA)

Precambrian The first of the eras of geologic time. See geologic time scale. (BWIP, EA)

precipitation (geochemical) The process by which mineral constituents are separated from magma or from solution by evaporation to form igneous rock. (EA)

precision Describes the closeness of agreement between randomly selected individual measurements or test results under specified conditions.

preclosure The period of time before and during the closure of the geologic repository. (10 CFR 960.2)

preliminary design (Title I) Continues the design effort using the conceptual design and the project design criteria as a basis for project development. Title I design develops topographical and subsurface data and determines the requirements and criteria that will govern the definitive design. Tasks include preparation of preliminary planning and engineering studies, preliminary drawings and outline specifications, life cycle cost analysis, preliminary cost estimates, and scheduling for project completion. Preliminary design provides identification of long-lead procurement items and analysis of risks associated with continued project development. (DOE 4700)

pressure gradient The rate of variation of pressure in a given direction in space at a fixed time. (BWIP)

pressurized water reactor (PWR) A nuclear reactor system that uses pressurized water to generate electricity. (EA)

pre-waste-emplacement Before the authorization of repository construction by the NRC. (10 CFR 960.2)

principal borehole Borehole RRL-2 was designated the principal borehole because it is the most important borehole for drilling the exploratory shaft. This borehole was centered at the location of the project repository and would provide stratigraphic and other information for drilling of the exploratory shaft. (EA)

probabilistic analysis A method to estimate the exceedance probability of a specified design event on the basis of a characterization of site region geologic structures and seismogenic sources, maximum magnitudes and recurrence statistics for each, and attenuation with distance of design event parameters. The method uses classical statistical processes for determination of means, standard deviations, and confidence levels of determined performance values. Uncertainties in these characterizations may be explicitly incorporated into the analysis.

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probabilistic safety assessment An estimate of the exceedance probability of a specific scenario consequence. It incorporates the results of a probabilistic analysis of a particular design event with an assessment of the likely consequences of that event, should it occur. Often, a number of events leading to a particular consequence must be considered for an adequate safety assessment. This type of assessment applies to both preclosure and postclosure analysis.

probable maximum flood (PMF) A statistical representation of the greatest flood to ever occur at a specific location. (EA)

probable maximum precipitation A statistical representation of the most precipitation that can reasonably be expected in a given area. (EA)

proglacial Immediately in front of or just beyond the outer limits of a glacier or ice sheet, generally at or near its lower end; said of lakes, streams, deposits, and other features produced by or derived from the glacier ice.

program An organized set of activities directed toward a common purpose or goal, undertaken or proposed in support of an assigned mission area. It is characterized by a strategy for accomplishing definitive objective(s), which identifies the means of accomplishment, particularly in quantitative terms, with respect to man power, materials, and facilities requirements. Programs are typically made up of technology base activities, projects, and supporting operations. (DOE 4700)

program assessment A determination of program condition based on a review of cost, schedule, technical status, and performance in relation to mission area assignments, program objectives, approved strategy, and milestones. (DOE 4700)

program changes The alterations that are made to the original general plan during the course of a site characterization study. Changes may be due to test results, unforeseen site conditions, or unanticipated conditions. Changes may also be to test procedures or resulting analyses due to actual site conditions. (BWIP)

program control The controls that are imposed within a site characterization study to ensure that a continuity exists through the course of the study and that reviews are performed that verify the judgments and assumptions made during the study. Program control parallels the design control applied to the physical design of the repository. (BWIP)

program (generic) One of five third-level elements in Section 8.3 of the Site Characterization Plan (8.3.1 Site Program, 8.3.2 Repository Program, 8.3.3 Seals Subsystem Program, 8.3.4 Waste Package Program, and 8.3.5 Performance Assessment Program). All but performance assessment are supported by four or more specific programs and a variety of investigations.

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program manager An individual in an organization or activity who is responsible for the management of a specific function or functions, for budget formulation, and for execution of the approved budget. The program manager receives an approved funding program from the Office of the Controller identifying program dollars available to accomplish the assigned function. (DOE 4700)

program objectives A statement or set of statements defining the purposes and goals to be achieved during performance of a program to fulfill a U.S. Department of Energy mission including the technical capabilities, cost, and schedule goals. (DOE 4700)

Program Office The U.S. Department of Energy-Headquarters organizational element responsible for managing a program. (DOE 4700)

program (specific) The fourth-level elements of Sections 8.3.1, 8.3.2, 8.3.3, and 8.3.4 of the Site Characterization Plan that normally group two or more supporting investigations. The annotated outline specifies the major investigations for only the four specific programs of Section 8.3.1 (site characterization). The investigations for specific programs within Sections 8.3.2, 8.3.3, and 8.3.4 have been developed in response to site-specific information needs.

project The organization, resources, and activities necessary to plan, schedule, budget, analyze, design, and produce a system. (BWIP)

project design criteria Those technical data and other project information developed during the project identification, conceptual design, and (or) preliminary design phases. They define the project scope, construction features, and requirements, and design parameters; applicable design codes, standards, and regulations; applicable health, safety, fire protection, safeguards, security, energy conservation, and quality assurance requirements; and other requirements. The project design criteria are normally consolidated into a document that provides the technical base for any further design performed after the criteria are developed. See also criteria, design. (DOE 4700)

project directive Correspondence issued by Basalt Waste Isolation Division to a project contractor participant authorizing a portion of work or procurement activity to proceed in accordance with stated parameters. Modifications and (or) revisions to project directives may be issued as required.

project management A management approach in which authority and responsibility for execution are vested in a single individual at a level below the general manager to provide focus on the planning, organizing, directing, and controlling of all activities within the project. In general terms, project management functions include assisting the program manager in preparing U.S. Department of Energy-Headquarters documents and establishing key milestones and overall

schedules. Other activities include developing and maintaining the project management plan; managing project resources; establishing and implementing management systems, including performance measurement systems; and, approving and implementing changes to project baselines. (DOE 4700)

project manager An official who has been assigned responsibility for accomplishing a specifically designated unit of work effort or group of closely related efforts established to achieve stated or designated objectives, defined tasks, or other units of related effort on a schedule for performing the stated work funded as part of the project. The project manager is responsible for the planning, controlling, and reporting of the project. (DOE 4700)

Project Management Plan (PMP) The basalt project document used to provide a description of the planned management system. (DOE-RL 1987a)

Project Office The organization responsible for administration of the Project Management System, maintenance of project files and documents, and staff support for officials throughout the project life cycle. (DOE 4700)

project participants Contractors, subtier contractors, and recipients of grants, memorandums of understanding, interagency agreements, and consultation and cooperative agreements.

protected species Plants and animals officially listed by the U.S. Fish and Wildlife Service. Species listed by the states as rare, threatened, or endangered are not included unless they also are on the federal list. (EA)

prototype An original model of something to be constructed; may be a model of a hardware device or system, a software program, and (or) the user interfaces to an information system. (IRM)

provenance The origin or birth, as applied to a deposit, primarily the source rocks from which these materials were derived. (BWIP)

P wave or compressional wave A disturbance traveling in an elastic medium; characterized by changes in volume and by particle motion parallel with the direction of wave movement. Also known as dilatational wave, irrotational wave, or pressure wave. (BWIP)

pyrite A common, brass-yellow mineral with a chemical composition of iron sulfide (FeS_2). (Commonly called fool's gold.) (EA)

pyroclastic Pertaining to clastic rock material formed by volcanic explosion or aerial expulsion from a volcanic vent; also, pertaining to rock texture of explosive origin.

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pyroxene A group of dark-colored, rock-forming silicate minerals that are closely related in crystal form and composition. The general chemical formula is A B Si_2 O_6, where A = Ca, Na, Mg, or Fe^{+2} and B = Mg, Fe^{+2}, Fe^{+3}, Fe, Cr, Mn, or Al with silicon, sometimes replaced in part by aluminum. (EA)

Q-List A list of geologic repository structures, systems, components, and activities that are important to safety and waste isolation and are thereby subject to the highest quality level (Quality Level 1) of the formal quality assurance program.

Q system The classification system for the rock-mass quality of the Cohassett flow dense interior; it estimates the rock-support requirements; rocks are classified as very poor to fair. (MP)

qualification (personnel) The characteristics or abilities gained through education, training, or experience, as measured against established requirements (e.g., standards or tests, that qualify an individual to perform a required function). (BWIP, QA1, QA3)

qualified site A site which, having been characterized in detail, is considered to be technically suitable for location of a repository and may be offered for formal licensing by the U.S. Department of Energy. (EA)

qualifying condition A condition that must be satisfied for a site to be considered acceptable with respect to a specific guideline. (10 CFR 960.2)

quality assurance (QA) All the planned and systematic actions necessary to provide adequate confidence that a structure, system, or component is constructed to plans and specifications and will perform satisfactorily.

quality assurance procedures/instructions Those procedures and (or) instructions, generated by the quality assurance organization, that provide instruction for the implementation and application of a quality assurance program requirements manual provided for the Basalt Waste Isolation Project. (BWIP)

quality assurance plan A documented purpose or goal established to give guidance to attainment of a controlled system satisfying specific quality requirements uinque to a project scope of work. (BWIP)

quality assurance program The formal organizational program implemented to ensure quality. The quality assurance program is documented in a quality assurance manual provided for the Basalt Waste Isolation Project that identifies the quality-related requirements to be fulfilled by the project and the individuals responsible for the completion of these requirements. (BWIP)

Quality Assurance Program Procedure (QAPP) A programmatic activity performed by or for the Basalt Waste Isolation Project in compliance with Basic and Supplementary Requirements of American National Standards Institute/American Society of Mechanical Engineers NQA-1 (ANSI/ASME 1983). The QAPP establishes standard methods for quality assurance administrative activities. (BWIP)

quality assurance record A completed document that furnishes evidence of the quality of items and (or) activities affecting quality. (BWIP, QA1)

quality concern report A form used by any Rockwell Basalt Waste Isolation Project organization personnel to identify and document potential or suspected nonconformances. (BWIP)

quality control (QC) Quality assurance actions that provide a means to control and measure the characteristics of an item, process, or facility to established requirements.

quality levels A formal method to classify items to establish the necessary controls to ensure they conform to specified requirements based on their importance to safety and/or waste isolation and the consequence of failure. (BWIP)

Quality Level 1 Those radiological health- and safety-related items and activities that are important to either safety or waste isolation and that are associated with the ability of a geologic nuclear waste repository to function in a manner that prevents or mitigates the consequences of a process or event that could cause undue risk to the radiological health and safety of the public. Items and activities important to safety are those engineered structures, systems, and components essential to the prevention or mitigation of an accident that could result in a radiation dose either to the whole body or to any organ of 0.5 rem or greater either at or beyond the nearest boundary of the unrestricted area at any time until the completion of the permanent closure of the repository. Activities important to waste isolation are those activities that must meet the criteria that address postclosure performance of the engineered and natural barriers to prevent the release of radionuclides. The criteria for items or activities important to safety and waste isolation are found in 10 CFR 60 and 40 CFR 191.

Quality Level 2 Those activities and items related to the systems, structures, and components that require a level of quality assurance sufficient to provide for reliability, maintainability, public and repository worker nonradiological health and safety, repository worker radiological health and safety, and other operational factors that would have an impact on the environment and on the U.S. Department of Energy and the Waste Management Program Office concerns.

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Quality Level 3 Those activities and items not classified as Quality Levels 1 or 2.

quality-related document Documents that specify quality requirements or prescribe activities affecting quality. (QA3)

quality survey of supplier The direct evaluation of prospective suppliers' capability to provide items or services in accordance with the requirements of the procurement documents prior to award of contract.

Quaternary faults Faults that have formed or experienced movement during the Quaternary Period. (BWIP, EA)

Quaternary igneous activity Intrusion or extrusion of molten rock material into or onto the Earth's crust during the Quaternary Period. (BWIP, EA)

Quaternary Period For the Basalt Waste Isolation Project, the beginning of the Quaternary Period is 1.67 m.y. ago. The time interval between 1.67 and 2 to 3 m.y. ago is included in the Tertiary Period.
NOTE: In 10 CFR 960.2, the U.S. Department of Energy has opted to use the definition "the second period of the Cenozoic Era, following the Tertiary, beginning 2 to 3 million years ago and extending to the present." See geologic time scale and Table A-2 (appendix).

rad Radiation absorbed dose, the basic unit of absorbed dose of ionizing radiation. A dose of 1 rad means the absorption of 100 ergs of radiation energy per gram of absorbing material. Related to but not the same as a rem. (BWIP, EA)

radiation Any or all of the following: alpha rays, beta rays, gamma rays, X-rays, microwaves, neutrons, high-speed electrons, high-speed protons, and other atomic particles, but not sound or radio waves or visible, infrared, or ultraviolet light. (BWIP)

radiation (ionizing) Particles and electromagnetic energy emitted by nuclear transformations that are capable of producing ions when interacting with matter; gamma rays and alpha and beta particles are primary examples. (BWIP, EA)

radiation concentration guide (RCG) The concentration of a particular radionuclide in air and water (different values) that has been judged by the International Commission on Radiation Protection to be safe for humans even if an individual were exposed to that concentration throughout his life. Also called the maximum permissible concentration. (BWIP)

radiation dose Amount of radiation received by individuals or a population usually expressed in terms of rem (roentgen equivalent man).

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radiation protection guides The officially determined radiation doses that should not be exceeded without careful consideration. These standards, originally set forth by the International Commission on Radiation Protection and the National Commission on Radiation Protection are now part of the U.S. Environmental Protection Agency regulations. They are equivalent to what were formerly called Maximum Permissible Exposures. (BWIP)

radiation zone An area that contains radioactive materials or radiation field in quantities significant enough to require control of personnel entry to the area. (EA)

radioactive Unstable in a manner shown by spontaneous nuclear disintegration with accompanying emission of radiation and particles consisting of alpha, beta, and gamma radiation. (MP)

radioactive decay Property of undergoing spontaneous nuclear transformation (disintegration) in which nuclear particles or electromagnetic energy (alpha particles, beta particles, or gamma photons) are emitted. (BWIP, EA)

radioactive material In general, any material that emits atomic particles or rays from the nuclei of its atoms. (BWIP, EA)

radioactive particulates Minute discrete particles that are radioactive. (BWIP)

radioactive waste High-level radioactive waste and other radioactive materials, including spent nuclear fuel, that are received for emplacement in a geologic repository. (10 CFR 960.2)

radioactive-waste facility A facility subject to the licensing and related regulatory authority of the U.S. Nuclear Regulatory Commission pursuant to Sections 202(3) and 202(4) of the Energy Reorganization Act of 1974. (10 CFR 960.2)

radioisotope A radioactive isotope of an element. (MP)

radiolaria Any actinopod belonging to the subclass radiolaria, characterized mainly by a siliceous skeleton and a marine pelagic environment. Range, Cambrian to present. In some classifications the radiolarians are grouped with the rhizopods.

radiolysis Decomposition (splitting) of chemical molecules (often water) due to interactions with radiation. (BWIP, EA)

radiometric Pertaining to the measurement of geologic time by the study of parent and (or) daughter isotopic abundances and known disintegration rates of the radioactive parent isotopes. See radiometric dating.

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radiometric dating The calculation of age in years of a material, based on the decay of naturally occurring radioactive isotopes. (EA)

radionuclide An unstable, radioactive isotope that decays toward a stable state at a characteristic rate by the emission of ionizing radiation(s). (BWIP, EA, MP)

radionuclide removal A process for separating the radionuclides from the chemical waste salts; usually performed to reduce the volume of nuclear waste material. (BWIP)

radionuclide retardation The process or processes that cause the time required for a given radionuclide to move between two locations to be greater than the groundwater travel time because of physical and chemical interactions between the radionuclide and the geohydrologic unit through which the radionuclide travels. (10 CFR 960.2)

radionuclide retardation factor A characteristic (usually chemical) of the hydrological or geochemical regime that slows the migration or transport of a radionuclide by sorption or other processes. The radionuclide retardation factor gives the ratio of the groundwater velocity to the solute velocity. (BWIP)

radiotoxicity The property of a material of being able to adversely affect biological organisms through the mechanism of nuclear radiation. (BWIP)

radwaste Short for radioactive waste. (BWIP, EA)

real time Pertaining to actual time during which physical process transpires.

reasonable assurance

(a) The process of determining the quantitative and (or) subjective acceptability of site characterization findings based on the written record. NOTE: Although this term is discussed in the Statements of Consideration that are part of 10 CFR 60, the definition of the term with respect to specific information in support of a license application is subject to judicial interpretation and (or) U.S. Nuclear Regulatory Commission staff judgment during the licensing process. (BWIP)

(b) As related to waste isolation: a qualitative judgment that depends on (1) defense-in-depth using diverse barriers, (2) diverse testing methods for a parameter, (3) diverse analysis methods for predicting performance, (4) a margin between predicted results and regulatory limits, and (5) technical consensus.

reasonably achievable (to the extent) That which is shown to be reasonable considering the costs and benefits of potential mitigative measures or reasonable courses of action in accordance with requirements of the National Environmental Policy Act of 1969.

reasonably available technology Technology that exists and has been demonstrated or for which the results of any requisite development, demonstration, or confirmatory testing efforts before application will be available within the required time period. (10 CFR 960.2)

recharge The process by which water is absorbed and added to the zone of saturation, either directly into a geologic formation, indirectly by way of another formation, or indirectly through unconsolidated sediments. (BWIP, EA)

recharge area In groundwater hydraulics, the area where surface water enters an aquifer. (BWIP, EA)

recommended practice The work procedures that are adopted for the conduct of technical activities such as field or laboratory work. In general, recommended practices are derived from standards development undertaken by organizations such as the American Society for Testing Materials. (BWIP)

redox (oxidation-reduction) See oxidation and (or) reduction. (EA)

reduction (chemical) Gain of electrons by a constituent of a chemical reaction. See oxidation.

redundancy The configuration of additional equipment (usually hardware but sometimes software) that allows operation to continue if the main operating equipment fails. (IRM)

reference repository design A conceptual repository design developed to reduce to practice the current state of knowledge. It is useful in site selection to identify potential unfavorable site characteristics. The value of design changes can be judged by comparison of the new design to the expected performance of the reference system. (BWIP)

reference repository location (RRL) The highest ranked candidate site on the Hanford Site for repository construction as determined by the screening process. NOTE: The reference repository location (Fig. A-3 and A-6, appendix) is smaller than either the controlled area or the controlled area study zone. (EA)

regolith The superficial mantle of unconsolidated debris that nearly everywhere covers the solid or "bed" rock and forms the surface of the land. It comprises rock waste of all sorts, volcanic ash, glacial drift, alluvium, windblown deposits, vegetal accumulations, and soils. In the Pasco Basin, the basin-filled sediments that overlie the basalt. See overburden. (BWIP, EA)

regulated area A radiation area, or otherwise controlled area, access to which is limited and controlled. (BWIP, EA)

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release The process by which contaminants leave human direct control and are dispersed to the environment. Releases may be scheduled, controlled, intentional, or accidental. (BWIP, EA)

release limit A regulatory limit on the concentration or the amount of radioactive material released to the environment in an industrial situation; usually expressed as a radiation dose. (EA)

reliability The probability that a system or component, when operating under stated environmental conditions, will perform its intended function adequately for a specified interval of time.

reliability analysis An analysis that estimates the reliability of a system or component.

remotely handled waste Waste that requires shielding in addition to that provided by its container in order to protect people nearby, because its surface dose rate precludes safe direct handling. May be transuranic or nontransuranic waste. (BWIP)

report A document that gives information for record purposes. (BWIP)

repository (Federal) Synonymous with "geologic repository." (10 CFR 960.2)

repository backfill Material used to fill portions of the repository or the entire repository to provide structural support or engineered barriers to radionuclide transport. (BWIP)

repository closure Synonymous with "closure." (10 CFR 960.2)

repository construction All excavation and mining activities associated with the construction of shafts, shaft stations, rooms, and necessary openings in the underground facility, preparatory to radioactive-waste emplacement, as well as the construction of necessary surface facilities, but excluding site characterization activities. (10 CFR 960.2)

repository horizon The elevation or rock formation at which the waste is emplaced below the Earth's surface. (BWIP)

repository isolation zone (RIZ) The stratigraphic interval within the controlled area study zone (CASZ) that is needed or may be needed to meet waste containment or isolation requirements. This interval lies between the top of the Priest Rapids Member of the Wanapum Basalt and the contact between the N2 and R2 magnetostratigraphic units in the Grande Ronde Basalt.

The primary isolation zone is the stratigraphic interval within the RIZ lying between the top of the Vantage interbed or at the Vantage horizon and the base of the Umtanum flow.

The secondary isolation zones are stratigraphic intervals within the CASZ, adjacent to the primary isolation zone; within the RIZ they extend from the Vantage interbed to the top of the Priest Rapids Member of the Wanapum Basalt and from the Umtanum flow to a zone 3 to 6 flows or flow units below the Umtanum flow. See Figure A-1 (appendix).

repository operation All of the functions at the site leading to and involving radioactive-waste emplacement in the underground facility, including receiving, transportation, handling, emplacement, and, if necessary, retrieval. (10 CFR 960.2)

repository site The place, both at and below the surface, where the repository and ancilliary facilities are constructed. This includes surrounding buffer zone and has a surface area of several square meters (miles). (BWIP)

repository subsystem One of three subsystems of the BWIP mined geologic disposal system that provides the surface and subsurface facilities and operational support for performing radioactive waste onsite transport, receipt, inspection, handling, placement, and disposal activities.

repository support facilities All permanent facilities constructed in support of site characterization activities and repository construction, operation, and closure activities, including surface structures, utility lines, roads, railroads, and similar facilities but excluding the underground facility. (10 CFR 960.2)

repository system The configuration of manmade features designed to act in harmony with the natural system to provide long-term containment and isolation of nuclear wastes and to provide for receipt, inspection, handling, emplacement, and potential retrieval of wastes during the operating phase. (BWIP, EA)

reprocessing The mechanical and chemical process by which irradiated nuclear fuel is separated into waste material to be disposed of and useful materials, such as thorium, uranium, and plutonium, to be reused as nuclear fuel. (MP)

reservation Any Indian reservation or dependent Indian community referred to in clause (a) or (b) of Section 1151 of Title 18, United States Code; or any land selected by an Alaskan Native village or regional corporation under the provisions of the Alaska Native Claims Settlement Act. (NWPA)

residual uncertainty Those inherent uncertainties in data, modeling, and assumed future conditions that cannot be eliminated. (BWIP, EA)

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restricted area Any area to which access is controlled by the U.S. Department of Energy for purposes of protecting individuals from exposure to radiation and radioactive materials before repository closure, but not including any areas used as residential quarters, although a separate room or rooms in a residential building may be set apart as a restricted area. (10 CFR 960.2)

retrievability Capacity to remove waste from its place in isolation, using planned engineering procedures, with approximately the same level of effort and radiation exposure as required to place the waste. The definition implies that on retrieval there will be no loss of radioactive material or loss of waste package container integrity. (BWIP)

retrievable storage Storage of radioactive materials in such a manner as to preserve the ability to retrieve the stored material without loss of container integrity. (BWIP)

retrieval The act of intentionally removing radioactive waste from the underground location at which the waste had been previously emplaced for disposal. (10 CFR 60.2)

reverse fault A fault in which the hanging wall appears to have moved upward relative to the footwall. (EA)

rhyolitic Characteristic of a group of extrusive igneous rocks, generally porphyritic and exhibiting flow texture with phenocrysts of quartz and alkali feldspar in a glassy to cryptocrystalline groundmass (rhyolite). (MP)

Richter magnitude See Richter scale.

Richter scale An earthquake magnitude scale developed in 1935 by the seismologist C. F. Richter. Very small earthquakes, or microearthquakes, can have negative magnitude values. See intensity (earthquake), magnitude (earthquake), and modified Mercalli scale. (BWIP)

rift (geologic) A long, narrow trough bounded by normal faults, or regional extent, often associated with volcanism. (EA)

right-lateral fault A fault, the displacement of which is right-lateral separation. In plain view, the apparent movement of the side opposite the observer is to the right. See dextral shear. (EA)

right-lateral offset An offset or fault, the displacement of which is right-lateral separation. See dextral shear.

risk A measure of the probability and severity of adverse effects (consequences); the expected detriment per unit of time to a person, property, or population from a given cause.

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risk analysis An anlysis that combines estimates of the probabilities of scenarios with estimates of the consequences of those scenarios, while considering the uncertainties associated with both.

rock bolt A bar, usually constructed of steel, which is anchored into predrilled holes in rock as a ground support device. (BWIP, EA)

rock bolting Method whereby rock bolts are driven and anchored into the walls of tunnels or shafts to provide roof and rib support in a mined operation. (BWIP)

rock burst A sudden rock failure associated with the release of strain energy in the rock mass. Such failures range in size from minor events that cause no substantial structural damage to underground excavations to large bursts that can collapse total sections of excavations with a seismeic disturbance equivalent to a small or medium earthquake.

rock drill A machine for drilling holes in rock for blasting, instrumentation, or rock testing purposes. (BWIP)

rock mass quality A description of the physical characteristics and mechanical behavior of the rock mass. Rock mass quality classifications are applied empirically to estimate expected underground excavation support and rock mass mechanical properties such as strength and deformation modulus. (EA)

rock mass rating (RMR) system The system used to classify the rock-mass quality of the Cohassett flow dense interior and estimate the rock-support elements; rocks are classified as fair to good. (MP)

rock salt The best known evaporite; forms by the precipitation of sodium chloride from saturated evaporating bodies of water in shallow basins. (MP)

roentgen A unit of gamma or X-ray radiation. The roentgen is that amount of gamma X-rays required to produce ions carrying 1 electrostatic unit of charge in 1 cm^3 (0.06 in^3) of dry air under standard conditions. It is also defined as the release by ionization of 83.8 ergs of energy per gram of air. (BWIP)

roentgen equivalent man (rem) A unit dose of ionizing radiation that has the same biological effect as one roentgen of X-rays; one rem approximately equals one rad for X, gamma, or beta radiation. Thus a rem is a unit of individual dose that allows comparison of effects of various radiation types as well as quantities. (BWIP, EA)

rubble zones Rock regions located at the base and top of basalt lava flows and most of the sedimentary interbeds; zones of relatively high permeability that commonly act as aquifers. (MP)

rupture As related to radioactive packaging, a breach of the barrier provided by the radioactive material container. (BWIP, EA)

safe shutdown earthquake (SSE) The earthquake producing the maximum vibratory ground motion for which structures, systems, and components are designed to remain functional. (BWIP, EA)

safety analysis report (SAR) A safety document showing that the facility and its safety-related systems can be operated with reasonable assurance of no undue risk to the health and safety of the public and with adequate provisions for the protection of property and the environment. (BWIP, EA)

safety assessment document (SAD) A brief, factual, and objective document that provides a general assessment of the potential environmental, safety, and health risks or consequences, determined on the identification and analysis of the hazards involved in the operations of the nuclear facility. (BWIP, EA)

safety dogs Spring-loaded safety catches used to stop the cage in the shaft should the supporting cable fail. The dogs are kept off the guides by the tension of the supporting cable, but the instant this tension is released, heavy springs snap metal points against the shaft guides. (BWIP)

salt The common mineral species halite (NaCl) and any included impurities. (EA)

sample

(a) A material, representative of a whole, from which specimens are removed. A sample is not materially altered when removing specimens. Duplicate specimens can, if requested, be obtained from the sample to repeat a test. From a technical standpoint, a sample is a limited-lifetime record. The lifetime of a sample is governed by physical characteristics of the sample and must be determined on a case-by-case basis by cognizant technical personnel.

(b) To take periodically a portion of the material of interest for analysis, assuming this sample to be representative of all material.

sample interval The actual lithologic sample (with a definite starting and ending footage) removed from the approval interval. Samples other than core do not have a starting and ending footage.

saturated zone That part of the Earth's crust beneath the water table in which all voids, large and small, are ideally filled with water under pressure greater than atmospheric. (10 CFR 960.2)

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scalar A quantity that has magnitude only and no direction, in contrast to a vector. (EA)

scanning-transmission electron microscope A type of electron microscope that scans with an extremely narrow beam of electrons transmitted through the sample. The detection apparatus produces an image whose brightness depends on the atomic number of the sample. (EA)

scenario A particular chain of hypothetical circumstances often used in performance analysis to model possible events. (BWIP, EA)

scenario analysis The process of identifying scenarios and estimating the probability of their occurrences.

scoria Vesicular, cindery crust on the surface of andesite or basaltic lava, the vesicular nature of which is due to the escape of volcanic gases before solidification. (EA)

screening (for site selection) The process of evaluating an area, on the basis of existing criteria or guidelines, to identify places that best fulfill the criteria or guidelines. (BWIP, EA)

screening area The Pasco Basin (approximately 4,144 km^2 (1,600 mi^2)). (BWIP, EA)

seal

(a) In the waste package, an engineered barrier designed to prevent the migration or intrusion of undesirable substances. (EA)

(b) Any device or system designed to create a nonleaking union between two mechanical or process-system elements (e.g., gaskets for pipe connection seals, mechanical seals for rotating members such as pump shafts, and liquid seals to prevent gas entry to, or loss from, a gas-liquid processing sequence). (BWIP)

sealed storage cask A large steel-lined reinforced-concrete cylinder that holds welded stainless steel canisters of spent fuel and is closed with a thick concrete shield plug and a welded steel lid. (MP)

sealing Impregnation of porous castings with resins to overcome porosity (e.g., reducing porosity of an anodic oxide film on aluminum and aluminum alloys by immersion in boiling water). (BWIP)

seals subsystem A repository subsystem composed of two subsystem elements, the shaft seals and borehole seals subsystems. Each element (subsystem) is composed of one or more barriers. Barriers placed in shafts and entry drifts compose the shaft seals subsystem. The borehole seals subsystem consists of barriers placed in boreholes originating from the Earth's surface, shafts, and underground excavations.

secondary containment The mechanical means that provides the second line of defense in preventing spread of contamination. (BWIP)

second-order fold A fold that occurs on the limbs or in the closure of a larger fold. Also referred to as a parasitic fold. See first-order fold. (EA)

Secretary The Secretary of the U.S. Department of Energy. (MP)

sedimentary rock Rock formed of sediment, especially (1) clastic rocks (e.g., conglomerates, sandstone, and shales) formed of fragments of other rock transported from their sources and deposited in water and (2) rocks formed by precipitation from solution (e.g., rock salt and gypsum) or from the secretions of organisms (e.g., most limestones). (MP)

seismic Pertaining to, characteristic of, or produced by earthquakes or earth vibrations. (BWIP, EA, MP)

seismicity The occurrence of earthquakes in space and time.

seismic reflection method A seismic exploration technique that produces a graphic cross-sectional representation of the disposition of rock units in the subsurface based on the reflection of artificially generated seismic waves by subsurface formations. (BWIP)

seismic refraction method A seismic exploration technique used for determining the depths to various rock formations. It is based on variations in the velocity at which artificially generated seismic waves travel through the subsurface. (BWIP, EA)

seismic zone A generally large area within which absolute seismic design requirements for engineered structures are uniform. (BWIP)

seismogenic province A geologic area characterized by a similarity of geologic structure, tectonic setting, and earthquake characteristics.

seismometer An instrument that receives seismic impulses and converts them into electrical voltage or otherwise makes them evident. Also known as a geophone. (EA)

self-absorption The absorption of radiation by the emitting substance. (BWIP)

sensitivity analysis A method of determining the importance of changes in data parameters or assumptions relative to a predicted outcome. (BWIP)

sere A sequence of ecologic communities that succeed one another in development from the pioneer stage to climax. Adj: seral.

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settling ponds Ponds next to chilling operations where the excavated mud or slurry is placed; the sediment that settles at the bottom of these ponds is also called muck. Pond muck is very fine-grained. (BWIP, EA)

sets

(a) A framework made from timber or steel for providing rock support in an excavation, shaft, or tunnel. (USBM)

(b) In a lined shaft, the system of cross members installed at fixed intervals to support guides, ladders, landings, utility lines, etc.

shaft (as related to a geologic repository) The penetration of the natural isolation barrier to provide access to the subsurface facility; it is usually of limited cross-sectional area compared to its depth. A more common definition is a manmade hole, either vertical or steeply inclined, that connects the surface with the underground workings of a mine or excavation. The difference between a shaft and a borehole is primarily in size and use. (A shaft can provide human-sized access.) (BWIP, EA)

shaft pillar The volume of rock around a shaft, or a group of shafts, from which underground openings are restricted in order that they not weaken the shaft.

shall A mandatory requirement. See may; shall, should, may; and should. (BWIP)

shall, should, may "Shall" denotes a requirement that must be met, "should" denotes a recommendation or guideline, and "may" denotes permission but not a requirement. "Shall" is implied unless "should" or "may" is used in the applicable text. See may, shall, and should.

shear

(a) A stress that causes contiguous parts of the body to deform or slide relative to each other in a direction parallel to their plane of contact.

(b) Surfaces and zones of failure shear strain, or surfaces along which differential movement has taken place. (EA)

shear zone A tabular zone of rock that has been crushed and brecciated by many parallel fractures resulting from shear strain. (MP)

shield An extensive (major) segment of the Earth's crust that has been relatively stable over a long period of time and that has exposed crystalline rocks mostly of Precambrian age; in general, represents the oldest rocks of the continent. (BWIP)

shielding The material interposed between a source of radiation and personnel for protection against danger of radiation; commonly used shielding materials are concrete, water, and lead. (EA)

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shipping cask A specially designed container used for shipping radioactive materials. (BWIP, EA)

shipping container An enclosure for the transport of packages that do not emit hazardous levels of radiation. (BWIP)

short-lived isotope A radioactive nuclide that decays so rapidly that a given quantity is transformed into its daughter products within a short period (usually those with a half-life of days or less). (BWIP)

should Considered a good practice and guideline, but not a mandatory requirement. See may; shall; and shall, should, may. (BWIP)

significant processes and events Scenarios having a probability of occurrence greater than 10^{-4} in the 10,000-yr period following repository closure. (This is equivalent to the need for scenarios required by the U.S. Environmental Protection Agency in 40 CFR 191 for repository performance assessment.)

significant sources of groundwater As used in 40 CFR 191, means (1) an aquifer that (i) is saturated with water having less than 10,000 mg/L of total dissolved solids, (ii) is within 762 m (2,500 ft) of the land surface, (iii) has a transmissivity greater than 2.5 m^2/d (200 gal/d/ft) provided that any formation or part of a formation included within the source of groundwater has a hydraulic conductivity greater than 1×10^{-6} m/s (2 gal/d/ft^2), and (iv) is capable of continuously yielding at least 26 L/min (10,000 gal/d) to a pumped or flowing well for a period of at least a year; or (2) an aquifer that provides the primary source of water for a community water system as of the effective date of 40 CFR 191. See Figure A-5 (appendix). (40 CFR 191)

silica A chemically resistant dioxide of silicon, SiO_2. (EA)

siliceous Said of a rock containing abundant silica, especially free silica rather than as silicates.

sill An intrusive tabular body of igneous rock that intrudes between layers of existing strata. See dike.

site A potentially acceptable site or a candidate site, as appropriate, until such time as the controlled area has been established, at which time the site and the controlled area are the same. (10 CFR 960.2)

site characterization Activities, whether in the laboratory or in the field, undertaken to establish the geologic conditions and the ranges of the parameters of a candidate site relevant to the location of a repository, including borings, surface excavations, excavations of exploratory shafts, limited subsurface lateral excavations and borings, and in situ testing needed to evaluate the suitability of a candidate site for the location of a repository, but not including preliminary

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borings and geophysical testing needed to assess whether site characterization should be undertaken. (10 CFR 960.2)

Site Characterization Plan

(a) A plan to conduct site characterization activities at a candidate site for a high-level waste repository, as required by the Nuclear Waste Policy Act of 1982 and 10 CFR 60.

(b) The program document that will reflect expected site conditions for each of the three sites recommended for site characterization. This document will provide the basis to identify the quantity and types of tests and analyses to be performed during site characterization. It will reflect the integration of the site characterization (exploratory shaft) facilities with the repository in terms of design, construction, and performance so that their impacts with respect to suitability of the site can be assessed. (MP)

site qualification All scientific and engineering investigations designed to demonstrate that a specific site has characteristics that will permit a repository facility to be licensed at the site. (BWIP)

site selection As described in 10 CFR 960, the process by which the decision is made as to which of several potentially qualified sites will be recommended for licensing repository construction and eventual repository operation. (BWIP)

site selection, final As described in 10 CFR 960, the process of choosing one of several banked sites for a high-level waste repository. This will include a comparison of environmental, technical, and institutional factors. The result will be a license application to be submitted to the U.S. Nuclear Regulatory Commission. (BWIP)

site subsystem

(a) A major subsystem of the mined geologic disposal system. The site subsystem contains the physical surface and subsurface subsystems. (DOE 1986b)

(b) The zone (volume) between the constructed repository and the accessible environment. See controlled area study zone.

siting The collection of exploration, testing, evaluation, and decision-making activities associated with the process of site screening, site nomination, site recommendation, and site approval for characterization or repository development. (10 CFR 960.2)

siting guidelines General guidelines for siting geologic repositories; issued by the U.S. Department of Energy as 10 CFR 960.

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siting research Activities including borings, surface excavations, shaft excavations, subsurface lateral excavations and borings, and in situ testing to determine the suitability of a site for a test and evaluation facility. (NWPA)

slabbing
(a) A stress-induced failure mechanism of the rock surrounding an excavation.

(b) A method of enlarging a drift or a room by excavating a slab or slice from the wall, usually by drilling and blasting. (USBM)

sleeve (as related to waste package) A metallic or nonmetallic liner located in the emplacement hole to aid in emplacement and possible retrieval of the waste package. (BWIP, EA)

slickensides Polished and smoothly striated surfaces that result from friction along a fault plane. (EA)

slip The relative displacement of formerly adjacent points on opposite sides of a fault, measured in the fault surface. (BWIP, EA)

sloughing The falling of loosened rock from the roof or walls of an underground excavation. (EA)

slump (geological) The downward slipping of a mass of rock or unconsolidated material of any size, moving as a unit or as several subsidiary units, usually with backward rotation on a more or less horizontal axis parallel to the cliff or slope from which it descends. See also landslide. (BWIP, EA)

social impacts Those impacts that deal primarily with a community's social organization and with perceptions of group and personal well-being. (MP)

solidification (in general) The process of incorporating waste with an immobilizing agent to produce a dry, stable solid form. (BWIP)
A common approach is the conversion of liquid high-level waste to glass (vitrification). (MP)

solid wastes (radioactive) Either solid radioactive material or solid objects that contain radioactive material that may or may not bear radioactive surface contamination as a consequence of being used in conjunction with a radioactive process or laboratory. (BWIP)

solubility The amount of substance that can be dissolved in a given amount of solvent. (EA)

solute The substance dissolved in a solvent. (BWIP, EA)

sonic log A geophysical log made by an instrument lowered and raised in a borehole or well that continuously records, as a function of depth, the velocity of sound waves as they travel over short distances in the adjacent rocks. The log reflects lithologic changes. (EA)

sorb To take and hold by either absorption or adsorption. (EA)

sorption The binding, on a microscopic scale, of one substance to another, such as by adsorption or ion exchange. Specific examples are the sorption of solutes, such as dissolved radionuclides, onto aquifer solids or waste package materials. (EA)

sorptive capacity The measure of a material's ability to sorb specific constituents from a liquid as it passes through the material. (BWIP, EA)

source inspection Inspection performed at the point of origin.

source, radiation Calibrated sample of radioactive material used to check instrument response and ability to measure; any point or area from which radiation originates. (BWIP)

source surveillance A review, observation, or inspection for the purpose of verifying that an action has been accomplished as specified at the location of material procurement or manufacture. (BWIP)

source term The kinds and amounts of radionuclides that make up the source of a potential release of radioactivity. (10 CFR 960.2)

spalling A small-scale rock failure where the rock breaks off in small, thin, flat surface slabs or flakes off at the surface. (USBM)

special sources of groundwater Those Class I groundwaters identified in accordance with the U.S. Environmental Protection Agency's groundwater protection strategy (EPA 1984) that (1) are within the controlled area encompassing a disposal system or are less than 5 km (approximately 3.1 mi) beyond the controlled area; (2) are supplying drinking water for thousands of persons as of the date that the U.S. Department of Energy chooses a location within that area for detailed characterization as a potential site for a disposal system (e.g., in accordance with Section 112(b)(1)(B) of the Nuclear Waste Policy Act of 1982); and (3) are irreplaceable in that no reasonable alternative source of drinking water is available to that population. (40 CFR 191)

specific activity Radioactivity per unit weight of radioactive material (Ci/kg). (BWIP)

specific heat Ratio of the thermal capacity of a substance compared to the thermal capacity of water (number of calories required to raise the temperature of a unit mass of a substance by 1 K in temperature). (BWIP, EA)

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specific yield The ratio of the volume of water that a given mass of saturated rock or soil will yield by gravity to the volume of that mass. See storage coefficient. (EA)

specimen A portion or split of a sample that is directly examined (e.g., tested, altered, consumed) during the course of an analysis. A specimen, not being a record, is retained at the discretion of the investigator.

speleothem Any secondary mineral deposit that is formed in a cave by the action of water.

spent fuel assemblies The arrangement of fuel rods, support grids, tie plates, and other structural members of the nuclear fuel removed from a reactor after irradiation. (MP)

spent fuel rods The irradiated metal tubes containing the uranium-bearing fuel pellets removed from a reactor. Part of the spent fuel assembly. (MP)

spent fuel waste The final form of spent fuel as waste that could include the fuel in some mechanically processed or disassembled form. (BWIP, EA)

spent nuclear fuel Fuel that has been withdrawn from a nuclear reactor following irradiation, the constituent elements of which have not been separated by reprocessing. (10 CFR 960.2)

spiracle A fume or vapor vent in a lava flow, formed by a gaseous explosion in lava that is still fluid, probably due to generation of steam from underlying wet material. (EA)

spoils The debris or waste material from a mine. The rock and other natural materials brought up to the ground surface during mining. Also called mined minerals. (BWIP, EA)

stabilizer Material or structure used to provide mechanical integrity and (or) chemical stability to the waste or waste package. (BWIP)

stable Geologic conditions such that the nature and rates of natural processes (e.g., erosion and faulting) have been, and are projected to be, such that their effects will not jeopardize the isolation of the radioactive waste. (10 CFR 60). NOTE: the term "stability" in the geologic sense has nothing to do with waste isolation.

statement of work (SOW) A document that contains instructions, technical objectives, and program/project requirements for the performance of supplier services.

stochastic Random. (EA)

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stochastic model A model whose inputs are uncertain and whose outputs are, therefore, also uncertain and must be described by probability distributions. (EA)

stop work order (SWO) A directive to stop any activity that is in direct violation of policies, Basalt Waste Isolation Project (BWIP) procedures, or that may result in bodily harm to personnel, damage to equipment, or have an overall unfavorable impact on budget or schedule of the project. An SWO will generally not be initiated unless other appropriate means have been exhausted (e.g., surveillance reports, corrective action requests). However, the BWIP Quality Assurance Manager may elect to stop work as a first means to correct an unsatisfactory condition if circumstances warrant. (BWIP)

storage (nuclear waste) Retention of spent nuclear fuel or radioactive wastes with the intent and capability to readily retrieve such fuel or waste for subsequent use, processing or disposal. (40 CFR 191)

storage coefficient The volume of water released from an aquifer or taken into storage per unit surface area of the aquifer per unit change in head. In a confined water body the water derived from storage with decline in head comes from expansion of the water and compression of the aquifer; similarly, water added to storage with a rise in head is accommodated partly by compression of the water and partly by expansion of the aquifer. See storativity. (BWIP)

storativity The volume of water released from or taken into storage in a vertical column of unit area when the water table or other piezometer surface per unit change in the hydraulic head normal to that surface. In an unconfined aquifer, it is approximately equal to the specific yield. (EA, MP)

strain Change in the shape or volume of a body as a result of stress; a change in the relative configuration of the particles of a substance. (EA)

stratigraphic setting The characteristics of the rock layers or other units in the geologic environment. (BWIP, EA)

stratigraphy The branch of geology that deals with the definition and interpretation of the rock strata, the conditions of their formation, their character, arrangement, sequence, age, distribution, and especially, their correlation by the use of fossils and other means of identification. (BWIP, EA, MP)

stratum A single bed or layer of rock regardless of thickness. (EA, MP)

streamline A groundwater flow path for which each particle passing through a given point follows the same path as the preceding particle.

stress In a solid, the force per unit area acting on any surface within it and variously expressed as force per unit area. (EA, MP)

strike The direction or trend of a structural surface (e.g., a bedding or fault plane) as it intersects the horizontal. (EA)

strike-slip fault A fault in which the net slip is horizontal or parallel to the strike of the fault. See dip-slip fault. (BWIP, EA)

study Applied in Section 8.3 of the Site Characterization Plan to refer to a combination of related tests and analyses in support of an investigation that is governed by a separate study plan. Each study normally corresponds to a specific investigation need identified in part A and subsequently incorporated into the relevant issue resolution strategy (or strategies) presented in Section 8.2.2.

subcontract Any agreement or arrangement between a contractor and any person (in which the parties do not stand in the relationship of an employer and an employee) (1) for the furnishing of supplies or services or for the use of real or personal property, including lease arrangements, which, in whole or in part, is necessary to the performance of any one or more contracts; or, (2) under which any portion of the contractor's obligation under any one or more contracts is performed, undertaken, or assumed. (DOE 4700)

subsidence Sinking of a part of the Earth's crust relative to adjacent parts. (BWIP)

substantial safety hazard A loss of safety functions to the extent that there is a reduction in excess of prescribed limits in the degree of protection provided to public or employee health and safety. Criteria appropriate for identifying a substantial safety hazard include the following:

- Exposure to or release of licensed material in excess of prescribed limits
- Major degradation of basic component important to safety or waste isolation
- Significant deviation involving design, construction, inspection, tests, or use of licensed facilities or material
- Deviations in laboratory or analytical data or test results that could result in significant deviations involving analysis of these data or use of the data in subsequent design considerations. (BWIP)

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substantially complete containment (period of) That time period after repository closure during which the quantity of any waste radioisotope released from all of the emplaced waste packages, considering anticipated processes and events, does not exceed the quantity of that radioisotope that is allowed to be released from the engineered barrier system during an equal time period after the end of containment; however, this condition does not apply to radioisotopes with radioactive decay half-lives of less than 45 yr.

subsurface facility

(a) The underground portions of the geologic repository operations area including openings, backfill materials, shafts, and boreholes as well as shaft and borehole seals. (10 CFR 60.2)

(b) The underground structure and the rock required for support, including mined openings and backfill materials, but excluding shafts, boreholes, and their seals. (10 CFR 960.2)
NOTE: 10 CFR 960.2 excludes shafts, boreholes, and their seals.

subsystem

(a) An integral part of a system that is itself a system; for example, the site, the repository, or waste package portions of the mined geologic disposal system.

(b) A group of assemblies or components, or both, combined to perform a single function. (BWIP)

subtier procurement Procurement by a supplier from a subsupplier of items or services. (BWIP)

suprabasalt That group of deposits that lie above, and are stratigraphically younger than, basalt.

surface facilities Repository support facilities within the restricted area. (10 CFR 960.2)

surface faulting Differential ground displacement at or near the surface caused directly by fault movement. It is distinct from nontectonic types of ground disruptions (e.g., landslides, fissures, and craters).
NOTE: This term is adopted from 10 CFR 100. (BWIP)

surface water Any waters on the surface of the Earth, including fresh and salt water, ice, and snow. (10 CFR 960.2)

surficial Of or pertaining to a surface, especially the Earth's surface. (BWIP)

synclinal axis In geology, the central line of a syncline, toward which beds dip from both sides. (BWIP)

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syncline Downfolded strata that form a trough. Beds dip toward the center of a syncline. (EA)

synthetic fault Subsidiary faults parallel to the main fault. (BWIP)

system The geologic setting at the site, the waste package, and the repository, all acting together to contain and isolate the waste. (10 CFR 960.2)

system engineering See systems engineering.

Systems Engineering Management Plan (SEMP) (DOE 1985b) The program document that will identify and document the procedures and responsibilities necessary for the engineering of a major, complex waste management system. (MP)

system or component performance How each element or a combination of all elements of the engineered barriers system of the geologic repository contributes to meeting the numerical performance objectives set forth in 10 CFR 60.

system performance The complete behavior of a repository system in response to the conditions, processes, and events that may affect it. (10 CFR 960.2)

systems engineering

(a) The application of scientific and engineering efforts to (1) transform an operational need into a description of system requirements and a system configuration through the use of an iterative process of definition, synthesis, analysis, design, test, and evaluation; (2) integrate the requirements and ensure compatibility of all physical, functional, and program interfaces; and (3) integrate the applicable scientific and engineering disciplines into the total BWIP effort in a manner that optimizes the total system definition and design to provide a licensable product that meets technical performance, quality assurance, and schedule and cost objectives.

(b) The engineering activities that provide a disciplined, systematic approach to planning and analysis. (MP)

systems integration A comprehensive attempt to consider all of the elements of any waste management program as part of a single system, optimized as a unit to best meet the program requirements. (MP)

systems study A special category of trade-off study that is separately listed and monitored in accordance with the OGR SEMP requirements. Systems studies are done when there is a significant impact of study results on (a) safety, isolation performance, life-cycle cost or schedule, or (b) interfaces between mined geologic disposal system subsystems or external waste management systems (transportation, waste source, or monitored retrievable storage).

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talus Loose rock fragments of any size or shape derived from and lying at the base of a steep slope. (EA)

technical conservatism A policy applied throughout the Basalt Waste Isolation Project to ensure that the final storage system will be sufficiently and conservatively safe. The mined geologic disposal system design and the analytical methods used to develop and demonstrate system effectiveness should be sufficiently conservative to compensate for residual design, operational, and long-term predictive uncertainties of potential importance to system effectiveness and should provide reasonable assurance that regulatory standards will be met. (BWIP)

tectonic Of, or pertaining to, the forces involved in, or the resulting structures or features of, "tectonics." (10 CFR 960.2)

tectonic activity Movement of the Earth's crust, such as uplift and subsidence and the associated folding, faulting, and seismicity. (BWIP, EA)

tectonic breccia A breccia formed as the result of crustal movements, usually developed in brittle rocks. Slickensides are commonly associated with tectonic breccia, and varying amounts of clay-like gouge may be present. (EA)

tectonic event An event causing or resulting from deformation of the Earth's crust (e.g., faulting, earthquake, folding, uplift). (BWIP)

tectonic features Indications that the rock has been moved since its original placement, including fault gouge, fault displacement, and folded rock. Shear zones are tectonic features that include fault gouge, fault displacement, brecciated zones, and increased fracture frequency. (EA)

tectonic fracture A fracture formed as a result of crustal stresses. Tectonic fractures may or may not have slickensides on their joining surfaces and are commonly associated with tectonic breccias. Includes fractures across which no measurable movement has occurred. (EA)

tectonic process A process or event contributing to the broad architecture of the outer part of the Earth; that is, to the regional assembling of structural or deformational features and the study of their interrelationships, origins, and evolution through time. Igneous activity, uplift, subsidence, folding, and faulting are examples of tectonic processes.

tectonic province A region of the Earth's crust characterized by a relative consistency of the geologic structural features contained therein. (BWIP, EA)

tectonics The branch of geology dealing with the broad architecture of the outer part of the Earth (i.e., the regional assembling of structural or deformational features and the study of the mutual relations, origin, and historical evolution). (10 CFR 960.2)

tectonism (diastrophism) Crustal movement produced by Earth forces such as the formation of plateaus and mountain ranges; the structural behavior of an element of the Earth's crust. (BWIP, EA)

telluric currents Natural electric currents that flow on or near the Earth's surface in large sheets. (BWIP)

tensile strength The ability of a material to resist a stress tending to stretch it or to pull it apart. (EA)

tensor A set of functions that relates different vector fields, such as might involve a change in coordinate systems. (EA)

tephra A general term for all clastic volcanic materials that, during an eruption, are ejected and transported through the air. (EA)

tephrochronology The collection, preparation, petrographic description, and approximate dating of tephra.

terminal storage Isolation and storage of radioactive waste operations for which no subsequent waste treatment or transportation operations are expected and conversion to disposal is considered possible. (BWIP, EA)

terrane A region within which a particular rock or group of rocks, topographic form, or underlying structure is prevalent. (BWIP)

Tertiary The earlier of the two geologic periods comprising the Cenozoic era, extending from 65 m.y. ago to approximately 2 m.y. ago. See geologic time scale. (BWIP, EA)

testing The determination or verification of the capability of an item to meet specified requirements by subjecting the item to a set of physical, chemical, environmental, or operating conditions. (BWIP)

thermal conductivity A measure of the ability of material to conduct heat (i.e., the time rate of transfer of heat by conduction) through unit thickness, across unit area for unit difference in temperature. Also termed heat conductivity.

thermal decrepitation The shattering of a rock mass or rock sample caused by the buildup of excessive pressures in contained fluids as a result of heating. (EA)

thermal expansion The increase in linear dimensions that occurs when materials are heated. (BWIP, EA, MP)

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thermal field The field or set of temperatures throughout a volume of material. Use of the term usually connotes temperatures that differ from point to point. (BWIP)

thermal gradient The rate of change of temperature with distance. (BWIP, EA)

thermal loading The application of heat to a system. Usually measured in terms of watt density. The thermal loading for a repository is the watts per hectare (per acre) produced by the radioactive waste in the active disposal area. (EA)

thermodynamic

(a) The branch of physics that attempts to derive relationships between properties of matter, especially those that are affected by changes in temperature.

(b) The interacting properties of a geologic system as they are affected by heat (temperature) and react physically to the stress.

(c) The energy evolved and consumed in chemical reactions and the relationship of this energy to equilibrium.

thermodynamic equilibrium Property of a system that is in mechanical, chemical, and thermal equilibrium. (BWIP)

thermomechanical Related to the transformation of heat energy into mechanical work. (EA)

thermophiles Organisms that prefer high temperatures.

third-order fold A fold that occurs on the limbs or in the closure of a second-order fold. See second-order fold. (EA)

tholeiite A compositional classification for basalt; silica oversaturated basalt characterized by low-calcium pyroxenes in addition to clinopyroxene and calcic plagioclase, and little or no olivine. Also known as "subalkaline basalt." (BWIP)

tholeiitic A type of basalt characterized by its lack of olivine. (EA)

thrust fault A fault with a dip of 45° or less in which the hanging wall appears to have moved upward relative to the footwall. (EA)

tiering Alternating sequences of entablature and colonnade in a basalt flow. (EA)

till An unsorted and unstratified mixture of glacial debris having a wide range of clast sizes. (EA)

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tillite A consolidated or indurated sedimentary rock formed by lithification of glacial till.

time scale, geologic See geologic time scale.

Title I All necessary preliminary engineering activities that follow conceptual design and precede the detailed design of a government-funded, U.S. Department of Energy-supervised facility to be built with capital dollars. (BWIP*)

Title II The final detailed design of a government-funded, U.S. Department of Energy-supervised facility to be built with capital dollars. (BWIP*)

Title III The construction phase of a government-funded, U.S. Department of Energy-supervised facility to be built with capital dollars, including inspection, as-building and acceptance of architect/engineer line item project drawings, and specifications. (BWIP*)

Title I Design Services See preliminary design.

Title III Design Services Those activities required to ensure that the project is constructed in accordance with the plans and specifications and that the quality of materials and workmanship is consistent with the requirements of the project. See definitive design.

tolerance The allowable deviation from a specified or true value. (BWIP)

tolerances A group of prescribed limits for specific properties of a particular measurement, instrument, or material.

topography The general configuration of a land surface or any part of the Earth's surface, including its relief and the position of its natural and man-made features. (BWIP, EA, MP)

tortuosity The inverse ratio of the length of a rock specimen to the length of the equivalent path of water within it. (EA)

total estimated cost The costs of the project, including the costs of land and land rights; engineering, design, and inspection costs; direct and indirect construction costs; and initial equipment necessary to place the plant or installation in operation whether funded out of operating or plant and capital equipment appropriations. (DOE 4700)

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*NOTE: The design phases for the Basalt Waste Isolation Project are conceptual design, advanced conceptual design, license application design, and final procurement and construction design.

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total project cost All generic research and development, operating costs associated with test and evaluation, and plant and capital equipment costs specifically associated with a project. It is the sum of the total estimated cost plus all other costs identifiable to the project. (DOE 4700)

to the extent practicable The degree to which an intended course of action is capable of being effected in a manner that is reasonable and feasible within a framework of constraints. (10 CFR 960.2)

toxic substance A substance that has the potential by chemical or radiological action to kill, injure, or impair living organisms. (BWIP)

tracer A radionuclide(s) or chemical introduced in minute quantities to a system or process for the purpose of using radiation or chemical detection techniques to follow the behavior of the process or system. (BWIP)

tracer testing A procedure in which a soluble substance (tracer) is added to a groundwater system at one location and its movement to another location is observed. Tracer testing is a technique by which groundwater flow directions, velocities, and other hydrologic properties of rocks can be estimated. It is also central to determining site geochemistry. (EA)

trade-off study A formal study wherein alternatives are formulated, established, evaluated, and presented with appropriate decision recommendations to satisfy systems requirements, performance criteria, and cost and schedule constraints. Trade-offs include selection, revision, and upgrading of the system design and system requirements.

transmissivity A coefficient relating the volumetric flow through a unit width of material to the driving force (hydraulic potential); a function of both the porous medium, fluid properties (including viscosity), and saturated thickness of the aquifer. Mathematically, it is the product of hydraulic conductivity and the thickness of the zone of the aquifer being measured. Transmissivity is a quantity defined in the study of groundwater hydraulics that describes the rate at which water may be transmitted through an aquifer. It is measured in m^2/d (ft^2/d) or equivalent units. (BWIP, EA)

transport path A route along or through which radionuclides could migrate. (BWIP, EA)

transuranic elements Those elements that have an atomic number higher than 92. They do not normally occur in nature and have to be produced artificially from uranium and thorium, either directly or indirectly by successive steps of transmutations. Examples include ^{93}Np, ^{94}Pu, ^{95}Am, ^{96}Cm, ^{97}Bk, ^{98}Cf, ^{99}Es, ^{100}Fm, ^{101}Md, and ^{102}No. (BWIP)

transuranic (radioactive) waste Waste containing more than 100 nCi of alpha-emitting transuranic isotopes, with half-lives greater than 20 yr, per gram of waste, except for (1) high-level radioactive wastes; (2) wastes that the U.S. Department of Energy has determined, with the concurrence of the U.S. Environmental Protection Agency Administrator, do not need the degree of isolation required by this Part (40 CFR 191) or (3) wastes that the U.S. Nuclear Regulatory Commission has approved for disposal on a case-by-case basis in accordance with 10 CFR 61. (40 CFR 191)

travel time (seismic) Time required for the wave to travel from the shotpoint to the recording point. (BWIP)

Triassic The first period of the Mesozoic era (after the Permian or the Paleozoic era, and before the Jurassic), thought to have covered the span of time between 225 and 190 m.y. ago; also, the corresponding system of rocks.

tribal organization A tribal organization as defined in the Indian Self-Determination and Education Assistance Act. (10 CFR 60)

trilateration Land survey based on triangulation, in which sides of the triangle are measured directly by use of an interferometer. (BWIP, EA)

troposphere That portion of the atmosphere next to the Earth's surface, in which temperature generally decreases rapidly with altitude, clouds form, and convection is active. In middle latitudes the troposphere generally includes the first 10 to 12 km (6.2 to 7.5 mi) above the Earth's surface.

tuff A rock formed of compacted volcanic ash and dust. (BWIP, EA)

tunnel A long, narrow subterranean passageway. (A tunnel is open to daylight at both ends.) See drift. (BWIP, EA)

unanticipated event (postclosure very unlikely event) A natural event, process, or human intrusion action that is projected to occur with a cumulative probability greater than 0.001 but less than 0.1 for the 10,000-yr period of regulatory applicability (40 CFR 191). Archaic use, unanticipated processes and events. In older documents, probabilities were "0.001 but less than 0.1" compared to the current "less than 0.02 but equal to or greater than 0.0001."

unanticipated processes and events Those processes and events affecting the geologic setting that are judged not to be reasonably likely to occur during the period the intended performance objective must be achieved, but which are nevertheless sufficiently credible to warrant consideration. Unanticipated processes and events may be either natural processes and events or processes and events initiated by human activities other than those activities licensed under this part. Processes and events initiated by human activities may only be found to

be sufficiently credible to warrant consideration if it is assumed that (1) the monuments provided for by this part are sufficiently permanent to serve their intended purpose; (2) the value to future generations of potential resources within the site can be assessed adequately under the applicable provisions of this part; (3) an understanding of the nature of radioactivity and an appreciation of its hazards have been retained in some functioning institutions; (4) institutions are able to assess risk and to take remedial action at a level of social organization and technological competence equivalent to, or superior to, that which was applied to initiating the processes or events concerned; and (5) relevant records are preserved and remain accessible for several hundred years after permanent closure. (10 CFR 60.2)

unconfined aquifer An aquifer containing groundwater that has a water table or surface at atmospheric pressure. (BWIP, EA)

unconformity (geologic) A break or gap in the geologic record, such as an interruption in the normal sequence of deposition of sedimentary rocks or a break between eroded metamorphic rocks and younger sedimentary strata. (EA)

underground facility The underground structure, including openings and backfill materials, but excluding shafts and boreholes and their seals. (10 CFR 60)

underground sources of drinking water Aquifers that have been designated as such sources of drinking water (40 CFR 146). Such a source has a yield of at least 0.7 L/s (1 gal/min). (BWIP)

unrestricted area Any area, access to which is not controlled by the licensee for purposes of protection of individuals from exposure to radiation and radioactive materials, and any area used for residential quarters. (10 CFR 60.2)
NOTE: For the Hanford Site, it is the area that falls outside the controlled area (radiation safety) except inside the Hanford Site boundary, at the Columbia River, State Route 240, U.S. Department of Energy leased land, State of Washington retained "fee title" land, roads from Richland to the Wye Barricade, and from the Wye Barricade to State Route 240 at Horn Rapids Dam, and the Fast Flux Test Facilities Visitor Center.

unsaturated medium That portion of a soil or rock column where void spaces are filled with a mixture of both air and water. This is opposite of a saturated medium where all voided spaces are water filled.

unsaturated zone The zone between the land surface and the water table. Generally, water in this zone is under less than atmospheric pressure, and some of the voids may contain air or other gases at atmospheric pressure. Beneath flooded areas or in perched water bodies, the water pressure locally may be greater than atmospheric. (10 CFR 960.2)

uplift (noun) A structurally high area in the crust, produced by movements that have raised or upthrust the rocks, as in a dome or arch. (BWIP, EA, MP)

urban area As defined for use in the 1980 census, incorporated and unincorporated places of 2,500 inhabitants or more. (EA)

vadose zone The unsaturated region of soil or the zone of aeration between the ground surface and the water table. (BWIP, EA)

valence state The potential chemical activity of an element related to configuration of outer electrons of constituent atoms. Some elements, including the actinides, have several possible valence states. When such an element moves to a higher valence state, it is said to have been oxidized; when it moves to a lower state, it is said to have been reduced. (BWIP)

validation (codes/models) Demonstration that a computer model adequately represents physical reality by comparison of computer modeling results with some physical test or observed condition.

validation (data) A systematic process for reviewing a body of data against a set of criteria to provide assurance that the data are adequate for their intended use. Data validation consists of data editing, screening, checking, auditing, verification certification, and review.

vent system A group of generally parallel fissures from which lava came to the surface. (EA)

vesicle A cavity of variable shape in lava formed by the entrapment of a gas bubble during solidification. (BWIP)

vesicle cylinder A cylindrical zone in a lava, in which there are abundant vesicles, probably formed by the generation of steam from underlying wet materials. (EA)

vesicle sheets A planar or near horizontal emplaced zone in a lava flow in which there are abundant vesicles. (EA)

vesicular zone Any significant portion of a basalt flow containing more than 2 vol% vesicles. The 2 vol%, an arbitrary value, is established as a minimum value for recording vesiculation percent. In core, "significant portion" is defined as that portion of core that contains a bulk 2 vol% over 0.3 m (1 ft) of core. In outcrop, "significant portion" is defined as a mappable unit appropriate for a particular scale of mapping. (BWIP)

vibratory ground motion See ground motion.

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viscosity Energy dissipation and generation of stresses in a fluid by the distortion of fluid elements; quantitatively, when otherwise qualified, the absolute viscosity. Also known as flow resistance, internal friction. (BWIP)

vitrify To solidify the waste in a glass form. (BWIP, EA)

volcaniclastic sediment A deposit dominated by transported fragments of volcanic origin. (EA)

volcanism The processes by which magma and its associated gases rise into the crust and are extruded onto the Earth's surface and into the atmosphere. (BWIP, EA)

vug A cavity, often with a mineral lining of different composition from that of the surrounding rock. (BWIP, EA)

waste Any spent nuclear fuel or radioactive waste being considered for isolation in a disposal system. (40 CFR 191)

waste canister See canister.

waste, cladding Cladding fragments and other structural materials from the spent fuel remaining in the dissolving vessel in chemical reprocessing. Usually a transuranic waste. See also cladding hulls. (BWIP, EA)

waste container Metallic or nonmetallic container enclosing the waste form that provides the primary containment function in accordance with 10 CFR 60. The term container connotes a portion of the containment system. (EA, MP)

waste form The radioactive waste materials and any encapsulating or stabilizing matrix. (10 CFR 60.2)

waste management The planning, execution, and surveillance of essential functions related to the control of radioactive (and nonradioactive) waste, including treatment, solidification, packaging, transportation, initial or long-term storage, surveillance, disposal, and isolation. (BWIP, EA)

waste matrix The material that surrounds and contains the waste and to some extent protects it from being released into the surrounding rock and groundwater. Only material within the container (or drum or box) that contains the waste is considered part of the waste matrix. (BWIP, EA)

waste package The waste form and any containers, shielding, packing, and other absorbent materials immediately surrounding an individual waste container. (10 CFR 60.2)

waste package subsystem A subsystem of the mined geologic disposal system. It is the physical subsystem concerned with providing the waste package.

waste treatment The chemical and (or) mechanical operations conducted to convert waste to a form suitable for disposal. (BWIP)

water budget The quantification of the amount of water entering, moving through, and leaving a flow system; sometimes called water balance. (EA)

watershed A drainage basin. (EA)

water table That surface in a body of groundwater at which the water pressure is atmospheric. (10 CFR 960.2)

Weichselian The term applied in northern Europe to the classical fourth and last glacial stage of the Pleistocene Epoch, after the Saale glacial stage; equivalent to the Wisconsinan.

Wiconsinan Pertaining to the classical fourth glacial stage (and the last definitely ascertained, although there appear to be others) of the Pleistocene Epoch in North America, following the Sangamonian interglacial stage and preceding the Holocene.

work element A technical activity required to satisfy all or part of a criterion and (or) to resolve an issue identified for siting and (or) developing a nuclear waste repository in basalt. See issue. (EA)

worst-case analysis An analysis based on assumptions and input data selected to yield a "worst impact" statement. (EA)

xeric Said of a habitat characterized by a low or inadequate supply of moisture; also, said of an organism or group of organisms existing in such a habitat.

xerophyte Adapted to dry conditions; a desert plant.

X-ray diffraction analysis Analysis of the crystal structure of materials by passing x rays through them and registering the diffraction (scattering) image of the rays. (EA)

yield zone That portion of the rock mass numerical model that indicates nonelastic (nonproportional) behavior of the rock mass material.

Young's modulus A modulus of elasticity in tension or compression, involving a change in length below the proportional limit. (EA)

zeolites Any of the various silicates that are analogous in composition to the feldspars and occur as secondary minerals in cavities, along fractures, and on joint planes in basaltic lavas. Occur also as authigenic minerals in sedimentary rocks. (BWIP, EA)

zooplankton The animal forms of plankton (e.g., jellyfish). They consume the phytoplankton.

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4.0 PRIMARY SOURCES OF DEFINITIONS

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4.3 CODE OF FEDERAL REGULATIONS

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10 CFR 60, Disposal of High-Level Radioactive Wastes in Geologic Repositories: Licensing Procedures, Title 10, Code of Federal Regulations, Part 60, U.S. Nuclear Regulatory Commission, Washington, D.C., 1987. [MF 4903]

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4.4 FEDERAL ACTS

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*A decision on July 17, 1987, by the U.S. Court of Appeals for the First Circuit has required the EPA to reconsider its postclosure standards (Subpart B) in 40 CFR 191. Consequently, the standards in 40 CFR 191 may be subject to revision in the future.

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APPENDIX

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Table A-1. Definition of Areal Extent.

Term	Basalt Waste Isolation Project Environmental Assessment	Areal extent (km^2)	Recommended Site Characterization Plan terminology
	Province	--	Pacific Northwest
Candidate Area	Region Geologic Setting	10,000's	Columbia Plateau
	Area	100-1,000's	Pasco Basin
	Location	100	Lower Part of the Upper Cold Creek Valley
Site	--	Approximately 250	Controlled Area Study Zone
	--	Approximately 100	Controlled Area
	Site	Approximately 50	Reference Repository Location (obsolete)
Facilities	--	Approximately 5	Surface Facilities
	--	Approximately 10	Underground

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Table A-2. Geologic Time Scale (BWIP).

Periods of time/ systems of rocks	Epochs of time/ series of rocks	Approximate age (yr x 10^6 BP*)
	Cenozoic Era	
Quaternary	Holocene (Recent)	0.01
	Pleistocene	1.67
Tertiary	Pliocene	5.0
	Miocene	22.0
	Oligocene	38.0
	Eocene	54.0
	Paleocene	65.0
	Mesozoic Era	
Cretaceous		
Jurassic		to 225
Triassic		
	Paleozoic Era	
Permian		
Carboniferous Periods		
Upper (Pennsylvanian)		
Lower (Mississippian)		
Devonian		to 570
Silurian		
Ordovician		
Cambrian		
	Precambrian	
No basis for worldwide subdivision		to 5,000

*BP = before present.

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PERIOD	EPOCH	GROUP	SUBGROUP	FORMATION	MEMBER OR SEQUENCE	SEDIMENT STRATIGRAPHY OR BASALT FLOWS	UNIT THICKNESS RANGES (m)		
QUATERNARY	Holocene				SURFICIAL UNITS	LOESS; SAND DUNES; ALLUVIUM ALLUVIAL FANS; LANDSLIDE; TALUS; COLLUVIUM	<3[a]	BUFFER ZONE	DEFENSE WASTE PROGRAM OPERATIONS SYSTEM
QUATERNARY	Pleistocene			Hanford	TOUCHET BEDS / PASCO GRAVELS		≤5[a] / ≤64[a]	BUFFER ZONE	DEFENSE WASTE PROGRAM OPERATIONS SYSTEM
TERTIARY	Pliocene					PLIO-PLEISTOCENE UNIT	0-26[a]	BUFFER ZONE	DEFENSE WASTE PROGRAM OPERATIONS SYSTEM
TERTIARY	Pliocene			Ringold		UPPER RINGOLD	0-33[a]	BUFFER ZONE	DEFENSE WASTE PROGRAM OPERATIONS SYSTEM
TERTIARY	Pliocene			Ringold		MIDDLE RINGOLD	55-100[a]	BUFFER ZONE	DEFENSE WASTE PROGRAM OPERATIONS SYSTEM
TERTIARY	Pliocene			Ringold		LOWER RINGOLD	0-17[a]	BUFFER ZONE	DEFENSE WASTE PROGRAM OPERATIONS SYSTEM
TERTIARY	Pliocene			Ringold		BASAL RINGOLD	6-60[a]	BUFFER ZONE	DEFENSE WASTE PROGRAM OPERATIONS SYSTEM
TERTIARY	Miocene	Columbia River Basalt Group	Yakima Basalt Subgroup	Saddle Mountains Basalt	ELEPHANT MOUNTAIN MEMBER	ELEPHANT MOUNTAIN FLOW	0-39.0	BUFFER ZONE	DEFENSE WASTE PROGRAM OPERATIONS SYSTEM
TERTIARY	Miocene	Columbia River Basalt Group	Yakima Basalt Subgroup	Saddle Mountains Basalt	ELEPHANT MOUNTAIN MEMBER	RATTLESNAKE RIDGE INTERBED	0-34.4	BUFFER ZONE	DEFENSE WASTE PROGRAM OPERATIONS SYSTEM
TERTIARY	Miocene	Columbia River Basalt Group	Yakima Basalt Subgroup	Saddle Mountains Basalt	POMONA MEMBER	POMONA FLOW	0-59.0	BUFFER ZONE	DEFENSE WASTE PROGRAM OPERATIONS SYSTEM
TERTIARY	Miocene	Columbia River Basalt Group	Yakima Basalt Subgroup	Saddle Mountains Basalt	POMONA MEMBER	SELAH INTERBED	0-30.8	BUFFER ZONE	DEFENSE WASTE PROGRAM OPERATIONS SYSTEM
TERTIARY	Miocene	Columbia River Basalt Group	Yakima Basalt Subgroup	Saddle Mountains Basalt	ESQUATZEL MEMBER	GABLE MOUNTAIN FLOW	0-36.3	BUFFER ZONE	DEFENSE WASTE PROGRAM OPERATIONS SYSTEM
TERTIARY	Miocene	Columbia River Basalt Group	Yakima Basalt Subgroup	Saddle Mountains Basalt	ESQUATZEL MEMBER	COLD CREEK INTERBED	0-36.6	BUFFER ZONE	DEFENSE WASTE PROGRAM OPERATIONS SYSTEM
TERTIARY	Miocene	Columbia River Basalt Group	Yakima Basalt Subgroup	Saddle Mountains Basalt	UMATILLA MEMBER	SILLUSI FLOW (DISCONTINUOUS); UMATILLA FLOW	20.7-73.2	BUFFER ZONE	DEFENSE WASTE PROGRAM OPERATIONS SYSTEM
TERTIARY	Miocene	Columbia River Basalt Group	Yakima Basalt Subgroup	Saddle Mountains Basalt	UMATILLA MEMBER	MABTON INTERBED	25.6-51.8	BUFFER ZONE	DEFENSE WASTE PROGRAM OPERATIONS SYSTEM
TERTIARY	Miocene	Columbia River Basalt Group	Yakima Basalt Subgroup	Wanapum Basalt	PRIEST RAPIDS MEMBER	LOLO FLOW	39.3-55.2	UPPER SECONDARY ISOLATION ZONE	COMMERCIAL WASTE PROGRAM REPOSITORY ISOLATION ZONE
TERTIARY	Miocene	Columbia River Basalt Group	Yakima Basalt Subgroup	Wanapum Basalt	PRIEST RAPIDS MEMBER	ROSALIA FLOW	16.5-33.5	UPPER SECONDARY ISOLATION ZONE	COMMERCIAL WASTE PROGRAM REPOSITORY ISOLATION ZONE
TERTIARY	Miocene	Columbia River Basalt Group	Yakima Basalt Subgroup	Wanapum Basalt	PRIEST RAPIDS MEMBER	QUINCY INTERBED (DISCONTINUOUS)	0-0.5	UPPER SECONDARY ISOLATION ZONE	COMMERCIAL WASTE PROGRAM REPOSITORY ISOLATION ZONE
TERTIARY	Miocene	Columbia River Basalt Group	Yakima Basalt Subgroup	Wanapum Basalt	ROZA MEMBER	ROZA FLOW (2 COOLING UNITS)	42.1-59.4	UPPER SECONDARY ISOLATION ZONE	COMMERCIAL WASTE PROGRAM REPOSITORY ISOLATION ZONE
TERTIARY	Miocene	Columbia River Basalt Group	Yakima Basalt Subgroup	Wanapum Basalt	ROZA MEMBER	SQUAW CREEK INTERBED (DISCONTINUOUS)	0-0.9	UPPER SECONDARY ISOLATION ZONE	COMMERCIAL WASTE PROGRAM REPOSITORY ISOLATION ZONE
TERTIARY	Miocene	Columbia River Basalt Group	Yakima Basalt Subgroup	Wanapum Basalt	FRENCHMAN SPRINGS MEMBER	SENTINEL GAP FLOW	50.9-64.6	UPPER SECONDARY ISOLATION ZONE	COMMERCIAL WASTE PROGRAM REPOSITORY ISOLATION ZONE
TERTIARY	Miocene	Columbia River Basalt Group	Yakima Basalt Subgroup	Wanapum Basalt	FRENCHMAN SPRINGS MEMBER	SAND HOLLOW FLOWS (2 FLOWS)	32.6-54.4	UPPER SECONDARY ISOLATION ZONE	COMMERCIAL WASTE PROGRAM REPOSITORY ISOLATION ZONE
TERTIARY	Miocene	Columbia River Basalt Group	Yakima Basalt Subgroup	Wanapum Basalt	FRENCHMAN SPRINGS MEMBER	SILVER FALLS FLOWS (1 TO 3 FLOWS)	19.8-47.9	UPPER SECONDARY ISOLATION ZONE	COMMERCIAL WASTE PROGRAM REPOSITORY ISOLATION ZONE
TERTIARY	Miocene	Columbia River Basalt Group	Yakima Basalt Subgroup	Wanapum Basalt	FRENCHMAN SPRINGS MEMBER	GINKGO FLOWS (2-3 FLOWS)	68.0-100.9	UPPER SECONDARY ISOLATION ZONE	COMMERCIAL WASTE PROGRAM REPOSITORY ISOLATION ZONE
TERTIARY	Miocene	Columbia River Basalt Group	Yakima Basalt Subgroup	Wanapum Basalt	FRENCHMAN SPRINGS MEMBER	UNNAMED INTERBED (DISCONTINUOUS)	0-3.7	UPPER SECONDARY ISOLATION ZONE	COMMERCIAL WASTE PROGRAM REPOSITORY ISOLATION ZONE
TERTIARY	Miocene	Columbia River Basalt Group	Yakima Basalt Subgroup	Wanapum Basalt	FRENCHMAN SPRINGS MEMBER	PALOUSE FALLS FLOW	9.1-25.0	UPPER SECONDARY ISOLATION ZONE	COMMERCIAL WASTE PROGRAM REPOSITORY ISOLATION ZONE
TERTIARY	Miocene	Columbia River Basalt Group	Yakima Basalt Subgroup	Wanapum Basalt	FRENCHMAN SPRINGS MEMBER	VANTAGE INTERBED	0-9.1	PRIMARY ISOLATION ZONE	COMMERCIAL WASTE PROGRAM REPOSITORY ISOLATION ZONE
TERTIARY	Miocene	Columbia River Basalt Group	Yakima Basalt Subgroup	Grande Ronde Basalt	SENTINEL BLUFFS SEQUENCE	FLOW 1	5.3-25.6	PRIMARY ISOLATION ZONE	COMMERCIAL WASTE PROGRAM REPOSITORY ISOLATION ZONE
TERTIARY	Miocene	Columbia River Basalt Group	Yakima Basalt Subgroup	Grande Ronde Basalt	SENTINEL BLUFFS SEQUENCE	FLOW 2	15.9-34.9	PRIMARY ISOLATION ZONE	COMMERCIAL WASTE PROGRAM REPOSITORY ISOLATION ZONE
TERTIARY	Miocene	Columbia River Basalt Group	Yakima Basalt Subgroup	Grande Ronde Basalt	SENTINEL BLUFFS SEQUENCE	ROCKY COULEE FLOW	40.2-57.0	PRIMARY ISOLATION ZONE	COMMERCIAL WASTE PROGRAM REPOSITORY ISOLATION ZONE
TERTIARY	Miocene	Columbia River Basalt Group	Yakima Basalt Subgroup	Grande Ronde Basalt	SENTINEL BLUFFS SEQUENCE	LEVERING FLOW (DISCONTINUOUS)	0-28.0	PRIMARY ISOLATION ZONE	COMMERCIAL WASTE PROGRAM REPOSITORY ISOLATION ZONE
TERTIARY	Miocene	Columbia River Basalt Group	Yakima Basalt Subgroup	Grande Ronde Basalt	SENTINEL BLUFFS SEQUENCE	COHASSETT FLOW	65.8-81.4	PRIMARY ISOLATION ZONE	COMMERCIAL WASTE PROGRAM REPOSITORY ISOLATION ZONE
TERTIARY	Miocene	Columbia River Basalt Group	Yakima Basalt Subgroup	Grande Ronde Basalt	SENTINEL BLUFFS SEQUENCE	BIRKETT FLOW	34.7-43.3	PRIMARY ISOLATION ZONE	COMMERCIAL WASTE PROGRAM REPOSITORY ISOLATION ZONE
TERTIARY	Miocene	Columbia River Basalt Group	Yakima Basalt Subgroup	Grande Ronde Basalt	SENTINEL BLUFFS SEQUENCE	FLOW 7	9.0-18.2	PRIMARY ISOLATION ZONE	COMMERCIAL WASTE PROGRAM REPOSITORY ISOLATION ZONE
TERTIARY	Miocene	Columbia River Basalt Group	Yakima Basalt Subgroup	Grande Ronde Basalt	SENTINEL BLUFFS SEQUENCE	FLOW 8	11.6-24.4	PRIMARY ISOLATION ZONE	COMMERCIAL WASTE PROGRAM REPOSITORY ISOLATION ZONE
TERTIARY	Miocene	Columbia River Basalt Group	Yakima Basalt Subgroup	Grande Ronde Basalt	SENTINEL BLUFFS SEQUENCE	McCOY CANYON FLOW	32.3-45.0	PRIMARY ISOLATION ZONE	COMMERCIAL WASTE PROGRAM REPOSITORY ISOLATION ZONE
TERTIARY	Miocene	Columbia River Basalt Group	Yakima Basalt Subgroup	Grande Ronde Basalt	SCHWANA SEQUENCE	UMTANUM FLOW	60.5-75.0	PRIMARY ISOLATION ZONE	COMMERCIAL WASTE PROGRAM REPOSITORY ISOLATION ZONE
TERTIARY	Miocene	Columbia River Basalt Group	Yakima Basalt Subgroup	Grande Ronde Basalt	SCHWANA SEQUENCE	VERY HIGH-Mg FLOW	0-22.6	LOWER SECONDARY ISOLATION ZONE	COMMERCIAL WASTE PROGRAM REPOSITORY ISOLATION ZONE
TERTIARY	Miocene	Columbia River Basalt Group	Yakima Basalt Subgroup	Grande Ronde Basalt	SCHWANA SEQUENCE	AT LEAST 3 FLOWS[b]	93.5[a]	LOWER SECONDARY ISOLATION ZONE	COMMERCIAL WASTE PROGRAM REPOSITORY ISOLATION ZONE
TERTIARY	Miocene	Columbia River Basalt Group	Yakima Basalt Subgroup	Grande Ronde Basalt	SCHWANA SEQUENCE	N_2-R_2 PALEOMAGNETIC CONTACT GREATER THAN 10 FLOWS	>1,750 TO BASE OF BASALT	LOWER SECONDARY ISOLATION ZONE	COMMERCIAL WASTE PROGRAM REPOSITORY ISOLATION ZONE

ELLENSBURG FORMATION

NOTE: TO CONVERT METERS TO FEET, MULTIPLY BY 3.28
[a]THICKNESS RANGE FOR THE REFERENCE REPOSITORY LOCATION ONLY.
[b]VALUE IS A MINIMUM ONLY (ONLY ONE BOREHOLE PENETRATED TO BASE OF LOWER BUFFER ZONE).

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Figure A-1. Stratigraphic intervals within the controlled area study zone pertinent to defense and commercial waste programs.

9 2 1 2 5 5 1 3 1 5

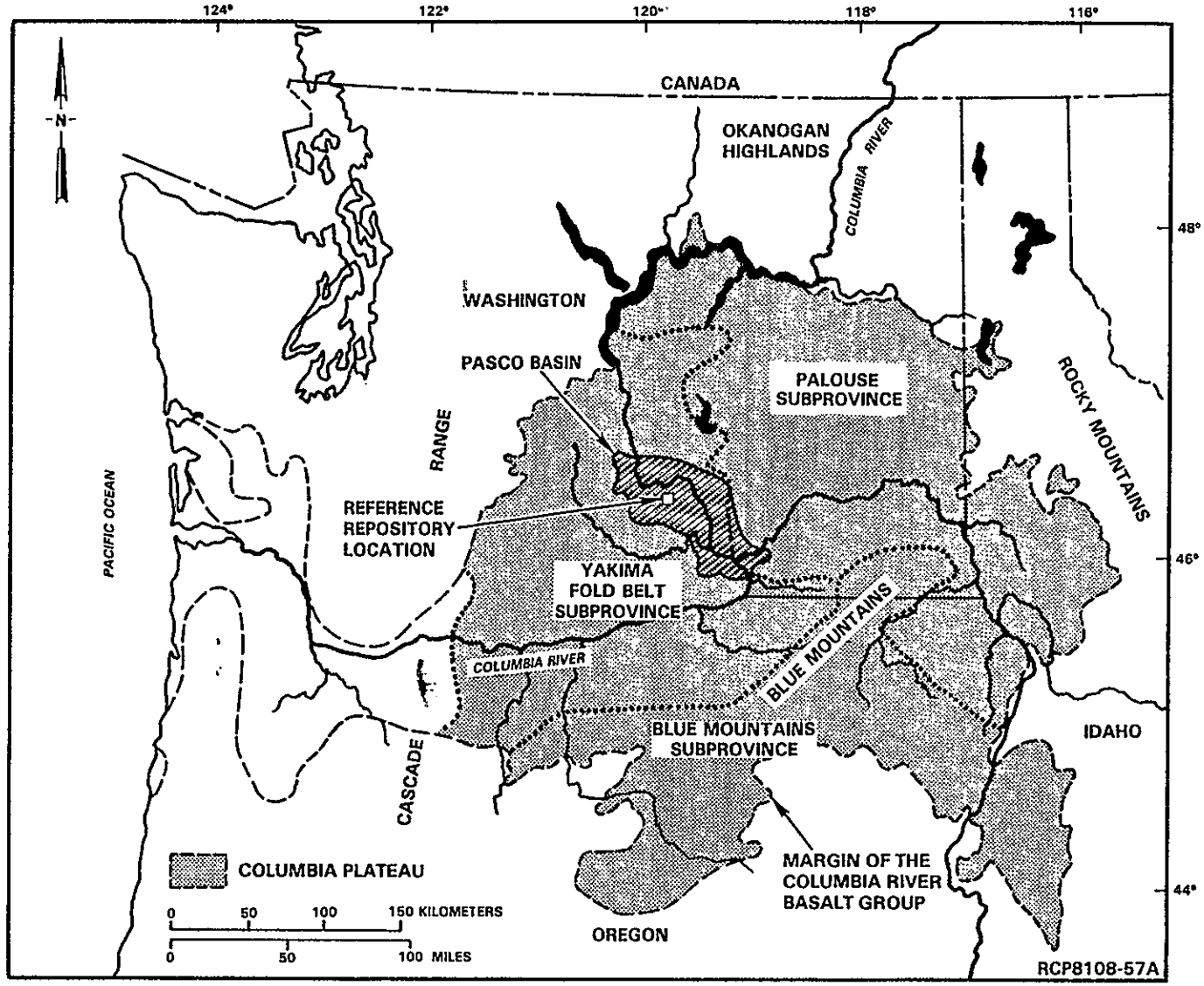

Figure A-2. Distribution of the Columbia River Basalt Group and extent of the Columbia Plateau.

CONSULTATION DRAFT

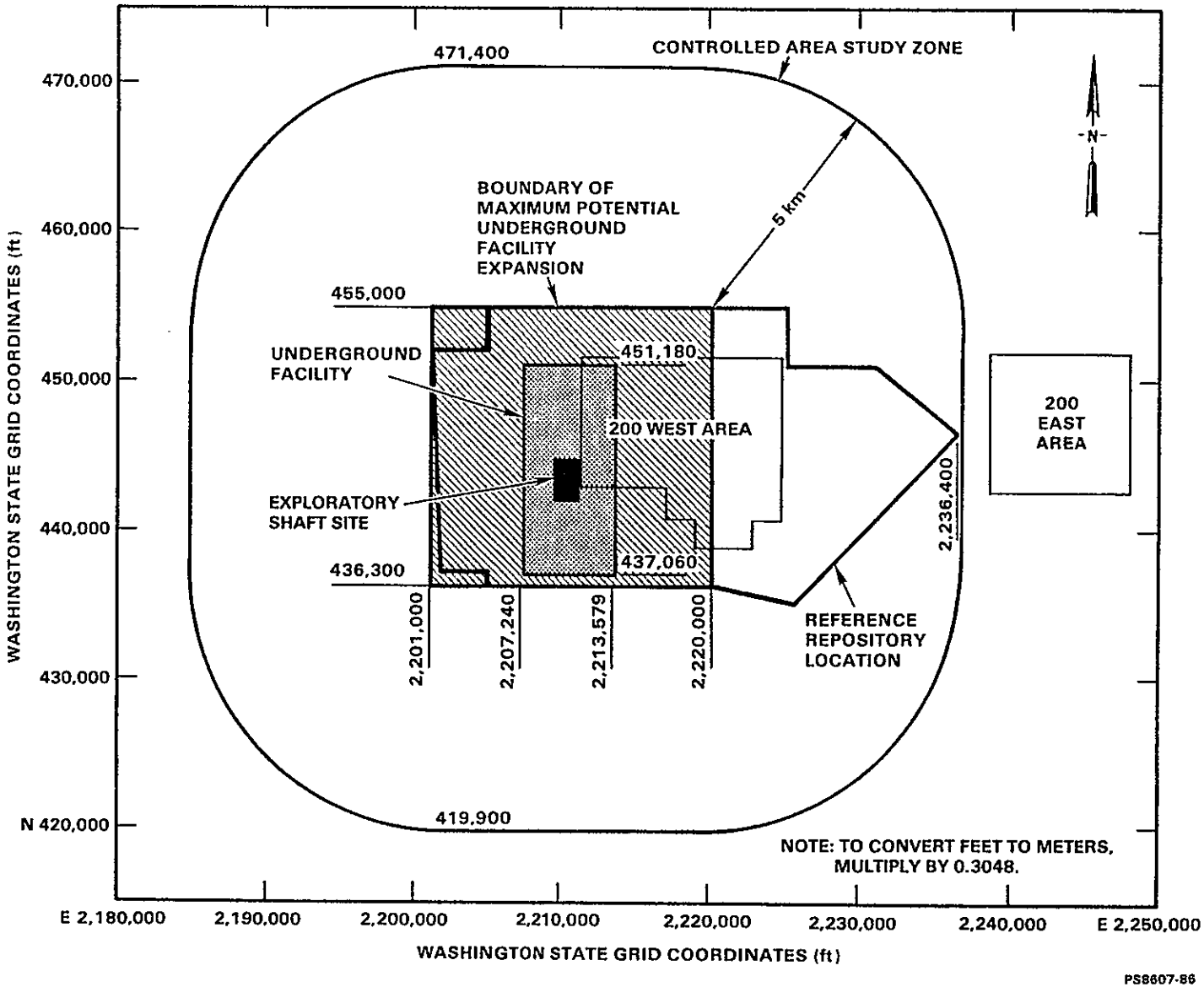

Figure A-3. Controlled area study zone.

CONSULTATION DRAFT

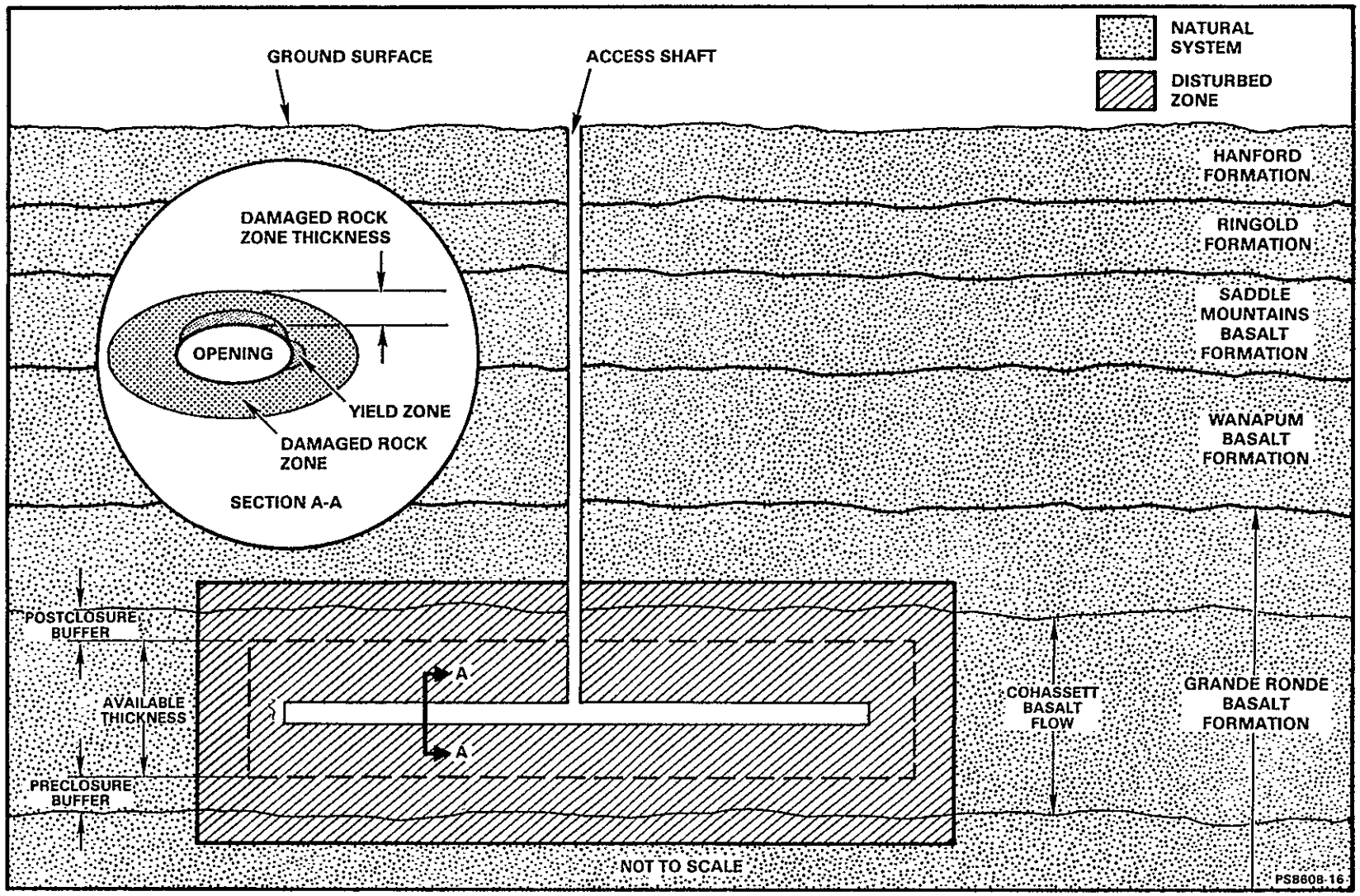

Figure A-4. Engineering system terms.

CONSULTATION DRAFT

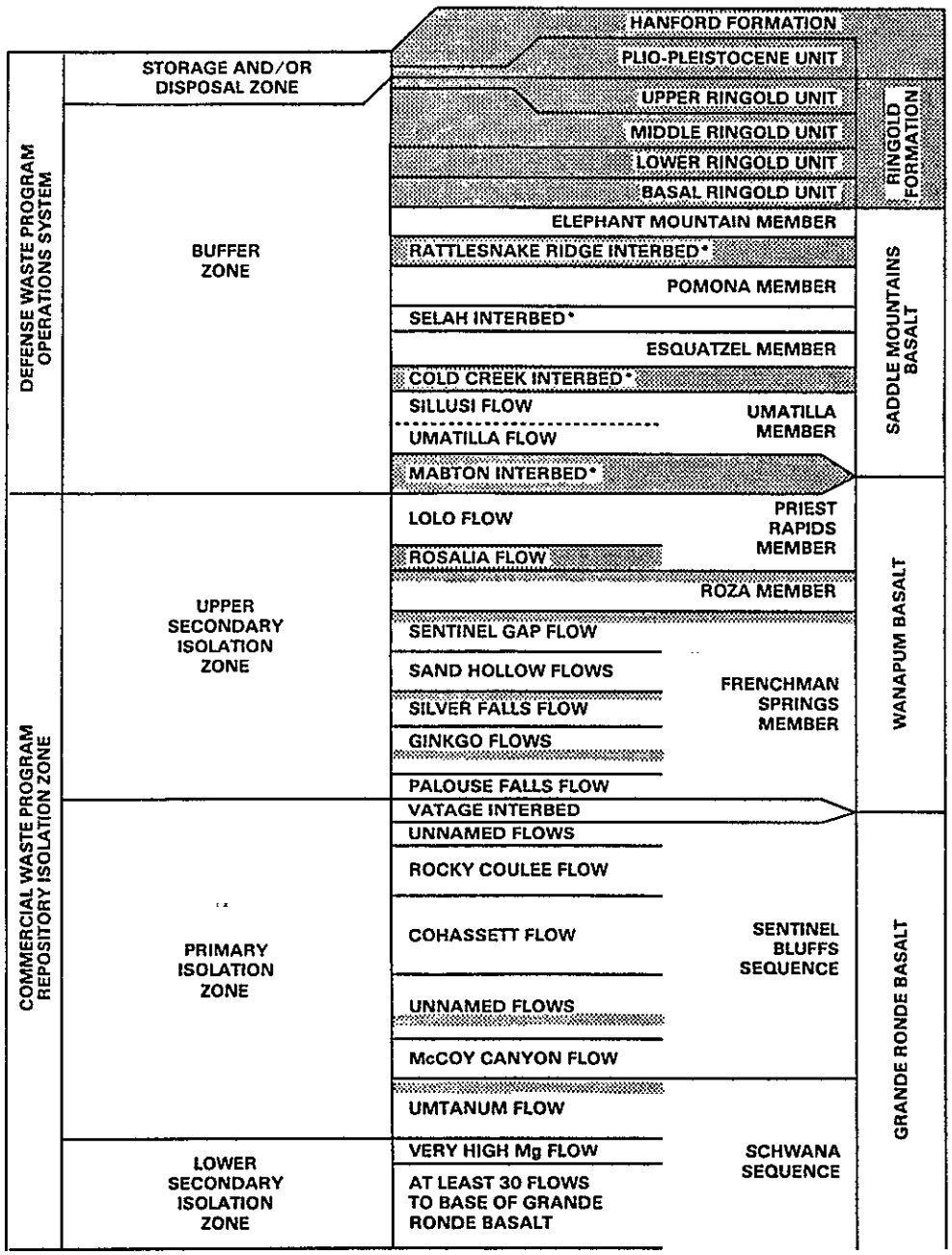

Figure A-5. Sources of groundwater beneath the controlled area study zone.

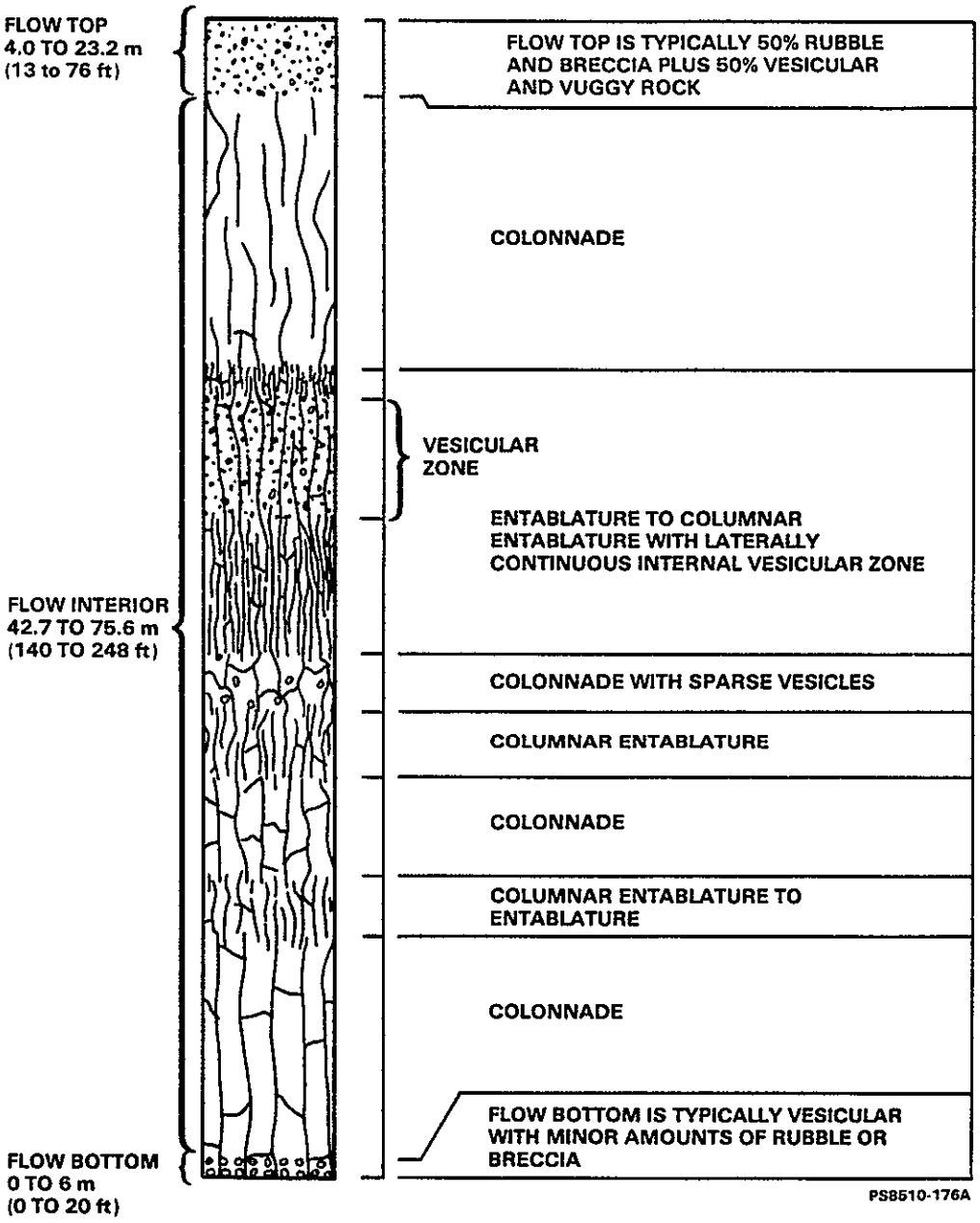

Figure A-6. Schematic section of the Cohassett flow at the reference repository location.

9 2 1 2 5 5 1 3 5 0

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9 2 1 2 5 5 5 1 3 5 1