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REGULATORY GUIDE

OFFICE OF NUCLEAR REGULATORY RESEARCH

REGULATORY GUIDE 4.17
(Task WM 404-4)

STANDARD FORMAT AND CONTENT OF SITE CHARACTERIZATION PLANS FOR HIGH-LEVEL-WASTE GEOLOGIC REPOSITORIES

*The substantial number of changes in this revision has made it impractical to indicate the changes with lines in the margin.

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INTRODUCTION

The Nuclear Regulatory Commission (NRC) licensing procedures for the disposal of high-level waste are contained in 10 CFR Part 60, "Disposal of High-Level Radioactive Wastes in Geologic Repositories." As part of the prelicensing procedures, the Department of Energy (DOE) is required to submit a site characterization* plan (SCP) to the NRC for a particular geologic repository operations area and prior to sinking shafts (§ 60.16).** The basic purpose of the SCP is simple: to provide a mechanism for identifying and delimiting the specific issues at a proposed repository site*** and to identify the plans for resolving those issues at an early time in order to avoid delays in the process. The SCP as reflected in the logic sequence and organization of this Standard Format and Content of Site Characterization Plans for High-Level-Waste Geologic Repositories (hereinafter "Standard Format") should accomplish the following:

1. Establish what is known about a site from site exploration activities completed to date,

2. Describe the issues that DOE has identified at a site in light of the results of investigations to date, and

3. Describe the detailed plans to resolve the issues identified.

NOTE: Following issuance of the proposed Revision 1 to Regulatory Guide 4.17 (Task WM 404-4, February 1985), the NRC and DOE held several public meetings on DOE's approach to implementing the proposed guidance. As a result, DOE developed an "Annotated Outline for Site Characterization Plans." The NRC provided comments on DOE's Annotated Outline in the meetings and concluded that Revision 4 of DOE's Annotated Outline, dated February 15, 1985, is a reasonable interpretation of and consistent with the regulatory guide. On May 7-8, 1986, DOE and NRC held a public meeting specifically on DOE's proposed implementation

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*As defined in 10 CFR Part 60, site characterization means the program of exploration and research, both in the laboratory and in the field, undertaken to establish the geologic conditions and the ranges of those parameters of a particular site relevant to the procedures under Part 60. Site characterization includes borings, surface excavations, excavation of exploratory shafts, limited subsurface lateral excavations and borings, and in situ testing at depth needed to determine the suitability of the site for a geologic repository but does not include preliminary borings and geophysical testing needed to decide whether site characterization should be undertaken.

**On January 17, 1985, NRC published proposed procedural amendments for incorporation into 10 CFR Part 60 (50 FR 2579). Final procedural amendments were promulgated on July 30, 1986 (51 FR 27158). Insofar as the material in this guide is concerned, the final rule is the same as the proposed rule.

***Site and other terms appearing in this Standard Format have the meanings set forth in § 60.2 of 10 CFR Part 60.

of Section 8.3 of the regulatory guide; agreements reached on the detailed guidance in that section are recorded in the meeting minutes. Copies of DOE's Annotated Outline and minutes from the meetings on the Annotated Outline and Section 8.3 of the site characterization are available in the Commission's Public Document Room.

Objective of Site Characterization

Site characterization will include exploration and research, both in the laboratory and in the field, to establish the geologic conditions at a site and the ranges of parameters that characterize the site. The objective of site characterization is to collect pertinent geological and other site characteristic information that will ultimately be needed for a license application, i.e., sufficient information about a site to support a finding, prior to construction, of reasonable assurance that there is no unreasonable risk to public health and safety.

Objectives of Site Characterization Plan

The purpose of the SCP is to provide a document in which DOE:

1. Describes the site, conceptual design of a repository appropriate to the site, waste form, waste packages, emplacement environment, and performance analysis in sufficient detail so that the planned site characterization program may be understood.

2. Identifies the uncertainties and limitations on site- and design-related information developed during site screening, including issues that need further investigation or for which additional assurance is needed.

3. Describes the detailed programs for additional work, including performance confirmation, to resolve outstanding issues and to reduce uncertainties in the data.

The SCP will provide a vehicle for early NRC, State, Indian tribal, and public input on DOE's data-gathering and development work so as to avoid postponing issues to the point where modifications would involve major delays or disruptions in the program. Early review of DOE's site characterization plans as presented in the SCP will provide an opportunity for NRC to evaluate whether DOE's proposed program is likely to generate data suitable to support a license application.

Following commencement of site characterization, DOE will provide the NRC Director of the Office of Nuclear Material Safety and Safeguards (NMSS) with semiannual reports (see Appendix A to this Standard Format) that will include the results of site characterization studies, including any new information that might affect the design assumptions concerning waste form and packaging and the planned repository itself. Semiannual reports will also include the identification of new issues, plans for additional studies to resolve these issues, the elimination of planned studies no longer necessary, and the identification of decision points reached and modifications to schedules, where appropriate.

Purpose, Applicability, and Use of This Standard Format

The purpose of this Standard Format is to suggest the types of information to be provided in the SCP in accordance with 10 CFR Part 60 and to establish a uniform format for presenting the information. Use of this format will help ensure the completeness of the information provided, will assist the NRC staff and others in locating the information, and will aid in shortening the time needed for the review process. This Standard Format represents a format that is acceptable to the NRC staff. However, conformance with the Standard Format is not required. SCPs with differing formats will be acceptable if they provide an adequate presentation of the information required by 10 CFR Part 60.

Any information collection requirements mentioned in this regulatory guide are exempt from the Paperwork Reduction Act (44 U.S.C. 3518(c)(1)).

The Standard Format is divided into two parts:

1. Part A provides guidance on the types of information needed to describe the site and the conceptual design (including the waste form and waste package and its emplacement environment) of a repository appropriate to the site. There is no threshold amount of data to be accumulated during the preliminary site exploration activities required prior to the submittal of an SCP. Rather, Part A provides guidance on how to submit information that is currently available.

2. Part B provides guidance on the presentation of the site characterization program, on the identification of unresolved issues, and on the plans to resolve these issues during site characterization.

In its review of Part B, the NRC will look for answers to the following questions:

a. Have the important information needs and unresolved issues been identified?

b. Does the SCP specifically address these information needs and present program plans to obtain the needed information?

c. Are the methods of testing and analysis proposed for the planned site characterization program appropriate?

d. Have alternative methods of testing and analysis been identified and evaluated, and has an adequate basis been provided for the selection of the methods to be used?

e. Will the data to be collected and the reliability of the collection methods and analyses be of adequate quality to support a future construction authorization application?

f. Have the testing plans been based on the performance requirements for the repository system and its components, and are the tests adequate to enable evaluation of whether or not the repository system and its components will satisfy the regulatory performance requirements?

The SCP will be principally evaluated according to the completeness of Part B, its most critical part.

In developing Part B of the SCP, DOE should ensure that attention is focused on those aspects of siting, development of waste form and packaging, and the conceptual design of a repository appropriate to the site that may require the most effort in the site characterization program. While the SCP must be complete in developing the issues of site characterization, it is important--particularly in initial planning phases--that those issues considered critical or most important to licensing be identified and given highest priority in the site characterization plans.

Part B should contain information about the planned tests at a level of detail sufficient to enable determination of whether adequate information for licensing will be produced. It should present definitive descriptions of the parameters to be controlled and measured in planned tests or analyses that show how the tests adequately bound the range of potential limiting conditions that are important to performance of the aspect of the repository being investigated.

The quality of data is virtually determined by the specific data-gathering methods and procedures that are used. In addition to questioning the relevancy and completeness of data supplied in the license application, the licensing process must explicitly address the question of whether or not the data are of adequate quality so that licensing determinations can be made with reasonable confidence. It is important, therefore, that specific methods to be used in data gathering and in the site characterization program be the subject of the prelicensing consultation between DOE and NRC.

NRC recognizes that the DOE program of site characterization will be a phased process. The depth of information provided may be determined considering the need for flexibility to account for the exploratory, developing nature of the investigations. NRC expects that plans included in the SCP may be better defined and more detailed for early phases of site characterization (e.g., testing in the exploratory shaft) and less detailed for later phases (e.g., testing in an underground facility with two shafts). However, for testing currently being conducted or planned as the first stage of future investigations, definitive plans must be documented. As DOE completes plans for later phases of site characterization, additional information should be submitted to NRC in semi-annual reports (see Appendix A to this Standard Format) or should be referenced in such reports and provided through other mechanisms provided for under the Procedural Agreement between the U.S. Nuclear Regulatory Commission and the U.S. Department of Energy entitled "Identifying Guiding Principles for Interface During Site Investigation and Site Characterization" (48 FR 38701).

In any event, all site characterization plans for gathering the information needed to conduct the full 10 CFR Part 60 evaluation of site suitability and design acceptability that will accompany the license application should be addressed fully in the SCP for each site.

Identification of Agents and Contractors

The DOE project management organization should be identified and the DOE technical projects and tasks described. Prime agents or contractors for site investigations, design, waste form and packaging, and performance analysis should also be identified. All principal consultants, outside service organizations, and key research groups to be involved with site characterization should be listed. The division of responsibility and lines of communication among these various parties should be delineated.

Supplemental Information

Detailed supplemental information not explicitly identified in this Standard Format may be provided in appendices to the SCP. Examples include:

1. Technical information in support of conceptual design features,
2. Reports furnished by consultants,
3. Summaries of how appropriate NRC regulations and guides were addressed, and
4. Portfolios of maps.

In cases where only representative data (e.g., selected geophysical data from selected borehole logs) are submitted, the original raw data should be accessible either at the site or other appropriate locations and should be readily available to NRC. Representative data should be of sufficient quality and quantity to permit an understanding of the nature and extent of the set of data actually available.

Style and Composition

Information should be presented clearly and concisely. Claims of adequacy of designs or design methods should be supported with technical bases.

Units of measurement (both fundamental and derived) should be given in the International System of Units (SI). If common industrial usage is in other units and the use of SI would be confusing, give the measurement in accepted units with SI units in parentheses.

The SCP should follow the numbering system and headings of the Standard Format at least down to the headings with three digits, e.g., 1.3.2 Tectonic History.

Avoid duplication of information. Similar or identical information may be requested in various sections of the Standard Format because it is appropriate to more than one portion of the SCP. In such cases, present the information in the principal section, and reference it appropriately in the other applicable sections.

Where numerical values are stated, the number of significant figures given should reflect the accuracy or precision to which the number is known. Where appropriate, estimated limits of error or uncertainty should be provided.

Abbreviations should be consistent with generally accepted usage throughout the SCP. Any abbreviations, symbols, or special terms not in general use should be defined when they first appear in the SCP.

Graphic presentations such as drawings, maps, diagrams, sketches, and charts should be used where the information can be presented more adequately or conveniently by such means or when the interpretation of data can be clarified. All information presented in drawings should be legible, symbols defined, and drawings not reduced to the extent that visual aids are necessary to easily interpret pertinent items of information presented in the drawings. When a series of maps is submitted, a common scale should be used whenever possible.

Bibliography

Bibliographic listings of documents or reports discussed in the SCP should appear at the end of the chapter in which they are first mentioned. For each report or document (e.g., articles in professional journals) listed in the bibliography, include the author, the title, the report or document number, and the date of publication and/or of submittal to NRC. For any reports that have been withheld from public disclosure as proprietary documents, nonproprietary summary descriptions of the general content of such reports should also be included in the bibliography. In cases where proprietary documents were used to obtain information, provide a nonproprietary summary of the document. Bibliographic listings may include not only documents and reports but also data on file at the site or project office (e.g., drill logs, hydrologic test data).

Physical Specifications

1. Paper Size

Text pages: 8-1/2 x 11 inches.

Drawings and graphics: 8-1/2 x 11 inches preferred; however, a larger size is acceptable provided the bound side does not exceed 11 inches, except where required for legibility, and the finished copy when folded does not exceed 8-1/2 x 11 inches.

2. Paper Stock and Ink

Suitable quality in substance, paper color, and ink density for handling and reproduction by microfilming or image-copying equipment.

3. Page Margins

A margin of no less than 1 inch should be maintained on the top, bottom, and binding side of all pages.

4. Printing

Composition: should be single-spaced text pages.

Type font and style: must be suitable for microfilming.

Reproduction: may be mechanically or photographically reproduced. Text pages should preferably be printed on two sides with the image printed head to head.

5. Binding

Pages should be punched for standard 3-hole loose-leaf binder.

6. Page Numbering

Pages should be numbered with the two digits corresponding to the chapter and first-level section numbers followed by a hyphen and a sequential number within the section, i.e., the third page in Section 4.1 of Chapter 4 should be numbered 4.1-3. Do not number the entire report sequentially. (Note that, because of the small number of pages in many chapters, this Standard Format is numbered sequentially throughout the document.)

PART A

STANDARD FORMAT AND CONTENT GUIDANCE FOR DESCRIBING THE SITE, WASTE FORM AND PACKAGE, AND CONCEPTUAL DESIGN OF A REPOSITORY

Part A of the Standard Format is designed to provide guidance on the types of information needed to describe the site to be characterized (§ 60.17). The main purpose of describing the site and conceptual design of a repository appropriate to the site (including a description of the waste form and waste packaging and environment) will be to provide information to allow issues to be identified and to provide information to support the site characterization program for resolving the issues. The descriptions should include the method of investigation used to obtain the information, the methods of evaluation used, and the limitations and uncertainties of either the method of investigation or the data used in the evaluation.

The NRC recognizes that, because of the generic nature of this Standard Format, some of the information requested in Chapters 1-6 (e.g., volcanic history) may not be appropriate to specific sites. The NRC also recognizes that the level of detail requested in some sections of Chapters 1-6 may not be available at the time the SCP for a particular site is submitted. There is no threshold amount of data to be accumulated prior to submittal of an SCP. This part of the Standard Format provides guidance on how to submit currently available information. For data that are available, the level of detail in the SCP should be the same as would be contained in the complete data base that will be used in licensing.

1. GEOLOGIC DESCRIPTION OF CANDIDATE AREA AND SITE

A description of the geology of the candidate area and site should be provided in this chapter. This information is needed to understand the relationship of the conceptual design of a repository appropriate to the specific site and the rationale for the proposed site characterization program.

Where geophysical techniques such as gravity, heat flow, and magnetic surveys have been conducted in support of geologic studies (e.g., subsurface stratigraphy or structure), this fact should be noted in the appropriate sections of this chapter. When geologic information has been obtained from the literature, the sources should be referenced.

1.1 Geomorphology

Describe the physiography, topography, geomorphic units, and geomorphic processes for the candidate area and site. Discuss the application of geomorphology to site screening and selection for characterization.

1.1.1 Physiography and Topography

Describe the physiographic provinces in which the candidate area and site are located. This description should include the province names, areal extent, relationships to surrounding provinces, distinguishing characteristics (e.g., structure style, elevation, relief), and major active processes modifying the present-day topography. This information should be provided by means of topographic maps of the candidate area and site using appropriate scales and contour intervals to support other studies associated with this site. When available, representative ground-level photographs, vertical and oblique aerial photographs, and satellite imagery should be included. Sources of information used to obtain the above descriptions should be listed.

1.1.2 Geomorphic Units

Describe each geomorphic unit by giving its name, areal extent, distinguishing characteristics, and other pertinent information. All units should be shown on a topographic map. Geomorphic units should be defined using a combination of factors influencing geomorphic processes such as near-surface geology and soil, relief, landform morphology, and biota.

1.1.3 Geomorphic Processes

Describe any geomorphic process that could affect the ability of the site to isolate radioactive waste. Each process should be discussed from the perspective of past, present, and estimated future activity. Emphasis should be placed on present and Quaternary processes since these may be the most useful for estimating future activity. However, information on older processes should also be given where it is useful for understanding present ground-water systems or predicting future changes (e.g., salt dissolution or collapse breccias) or where it can contribute to estimating the potential occurrence of future processes.

Each geomorphic process should be described, including (1) rate of activity, (2) frequency of occurrence and cycles, and (3) controlling mechanisms or factors.

1.2 Stratigraphy

Using available information, describe the stratigraphic framework of the candidate area and site, including both surface and subsurface geology. Distinguish between Quaternary and pre-Quaternary stratigraphic units.

Descriptions and illustrations (e.g., maps, columns, cross sections) should be given in sufficient detail, legibility, style, and quality to permit their evaluation by independent reviewers.

1.2.1 Surface Geology

Provide a map of the surface geology and, where the information is available, relate surface rock units to those in the subsurface. Where feasible, nationally recognized geologic symbols should be used.*

1.2.2 Stratigraphic Framework of Candidate Area

Provide a framework for the stratigraphy of the candidate area in the following manner:

1. Present a map of the candidate area. State the technical bases (e.g., sedimentary basin) for the boundary of the candidate area, and include all areas relevant to studies supported by stratigraphy.

2. Illustrate the stratigraphy and lithology of the candidate area using such materials as geologic maps, representative lithostratigraphic columns, and cross sections. Lithostratigraphic sequences should be characterized in three dimensions in sufficient detail to give clear orientation and order to the detailed descriptions of rock units in the candidate area. For each lithostratigraphic sequence, list major unconformities, the age, range of thickness, spatial extent, major rock units, and vertical and lateral variations. Present an overall geologic time sequence (periods, epochs, and ages) for the rock units of the candidate area.

3. Present appropriate genetic models for the origins and development of the rock sequences that include a general geologic history through time of the rock sequence and the processes that formed and altered the sequence. Include subjects such as sedimentary tectonics, source area, depositional and diagenetic environments, volcanism, plutonism, and metamorphism.

1.2.3 Stratigraphic Framework of Site

Describe the stratigraphy of the site, using surface and subsurface information when available. This information can be obtained from the literature or

*See Data Sheet Numbers 1-4, American Geological Institute, 5205 Leesburg Pike, Falls Church, Virginia 22041.

from the results of preliminary site exploration activities. Provide representative photographs and geophysical logs for the lithostratigraphic units when available. For wells that have been cored, representative driller logs, lithologic and geophysical logs, and core photographs should be provided.

Lithostratigraphic units can be formal (groups, formations, or members) or informal (sequences or lithofacies) and should represent the degree of subdivision of the rock mass necessary to permit an evaluation of the planned site characterization program.

Each lithostratigraphic unit should be described.* Descriptions should include but not be limited to:

1. The name, using established nomenclature,

2. Lithologic and mineralogic composition,

3. Diagnostic physical and paleontological characteristics useful for identification and correlation (e.g., color, sedimentary structures, texture, fabric, trace elements content, fossil content),

4. Physical characteristics significant to isolation of radioactive waste such as bedding, mineralogy, grain size, intergranular fillings, cement, and secondary mineralization,

5. Geophysical characteristics or signatures such as density, magnetic susceptibility, remanent magnetism, conductivity, and velocity profiles (surface and subsurface, including downhole),

6. Vertical and lateral variation of composition and characteristics and comparison to surrounding units (lithofacies maps),

7. Thickness and spatial extent (isopach maps, geologic columns, cross sections, fence or block diagrams),

8. Structure (specific attitude measurements or inferred structure from geophysical data) and its variation (reference other sections of the SCP as needed for detail),

9. Vertical and lateral relationships to surrounding rock units (contacts and unconformities),

10. Age, and

11. Genesis or origin of the unit, including rock formation processes and models (deposition, intrusion, extrusion) and rock alteration processes and models (metamorphism and diagenesis).

*See "Code of Stratigraphic Nomenclature," in the Bulletin of the American Association of Petroleum Geologists, Vol. 45, pp. 645-665, 1961, and subsequent revisions.

1.3 Structural Geology and Tectonics of Candidate Area and Site

Define the tectonic elements of the candidate area and site, and describe any pre-Quaternary and Quaternary structures present. If known, structural features that may create pathways from the depths of the conceptual design of a repository appropriate to the site to the accessible environment* should be described regardless of age. Structural features that provide information about the tectonic stability of the site should be described. In addition, structural features occurring in active areas of strain release that have constituted major tectonic boundaries in their geologic history or that may be reactivated to create tectonic instability should also be described. Appropriate models that describe both the static and dynamic conditions should be included.

1.3.1 Tectonic Framework

Discuss the tectonic framework of the candidate area and site. Identify those tectonic processes that have been active since the start of the Quaternary. Maps and cross sections that show all major tectonic features, including crystalline shields, sedimentary basins, uplifts, orogenic and fold belts, volcanics, major faults, and major joint sets, should be provided when available.

1.3.2 Tectonic History

Describe the tectonic history of the candidate area and site from the earliest recognizable tectonic elements through the end of the Pliocene. The tectonic history should include the age and sequence of development of all major crystalline shields, sedimentary basins, uplifts, orogenic and fold belts, volcanics, major faults, and major joint sets.

1.3.2.1 Volcanic History. The volcanic history should be described when applicable to a particular site or candidate area. Maps of the candidate area and site showing the distribution of extrusive and intrusive rocks should be provided.

If there is more than one period of volcanic activity in the candidate area or if there has been repeated volcanism during the Quaternary, a table listing the volcanic episodes should be included. The table should describe the type of extrusive or intrusive rock, composition of the volcanics, age, geometric relationship to other volcanics, and the stratigraphy of the surrounding rocks. A description of each major period of volcanism should be presented for each volcanic episode listed on the table.

The mineralogy and geochemistry of each volcanic unit should be presented in this section and referenced in other appropriate chapters of the SCP. Alternation, contact metamorphism, and mineralization of country rocks surrounding the flows should be discussed as well as any weathering and alternation of the volcanic rocks themselves. Fracturing and faulting associated with volcanism,

*For a definition of the term accessible environment, refer to § 60.2 of 10 CFR Part 60.

including attitude, spacing and size of fractures, and cross-cutting relationships among fractures in country and volcanic rocks, should be described.

The effects of the volcanism on the interstitial and secondary porosity and permeabilities of the country rocks and the effect of volcanism on the regional hydrogeology should be described. If this information is not currently available, present plans in Part B for obtaining it during site characterization.

Based on the Quaternary volcanic history, predict the potential for future volcanic activity in the candidate area with emphasis on the next 10,000 years. Consider the types of activity, volumes of material, and spatial and temporal probabilities.

1.3.2.2 Faulting History. The faulting history of the candidate area and site should be described. The description should include the distribution, causes, characteristics, attitude, spacing, length, strike direction, dip of the fault plane, and width and nature of the fault zone of the faults. This should be accompanied by a map showing the location, strike, and dip of all known and suspected faults. The extent to which faults may act as pathways to the accessible environment from the conceptual design of a repository appropriate to the site should be estimated if possible.

Provide information on surface offsets and net slip of all the Quaternary faults and the amount of basement offset associated with each fault. All assumptions for determining true offset should be explicitly stated. The movement history, including rate of displacement and recurrence interval, should be identified. Absolute and relative dating techniques should be applied where possible. If more than one period of Quaternary faulting is present within the candidate area or site, the fault systems of different ages should be tabulated, and the evidence for the age of each fault should be presented.

1.3.2.3 Folding History. The folding history of the candidate area and site should be discussed, and a map that shows the location and trend of fold belts in the candidate area should be included.

Describe the geometry, symmetry, wavelength and amplitude of the folds, their mode of origin (e.g., flexural slip), and their attitude relative to the earth's surface (upright, inclined, overturned, or recumbent). The trend and plunge of the fold axis and the strike and dip of the axial surface of each major fold, along with its sense of asymmetry, should be mapped. Cleavage, fractures, and faults associated and penecontemporaneous with the folding should be delineated from available information. Any change in porosity and permeability of the rocks due to folding should be discussed.

Describe the overall nature of the folding. "Thin-skinned" tectonics should be distinguished from "thick-skinned" or basement tectonics.

If more than one period of folding is present, the evidence that allows the relative and/or absolute dating of the individual episodes of folding should be included.

1.3.2.4 Jointing History. The jointing history of the candidate area and site should be described as thoroughly as possible. A map showing the location and trend of all known joint sets should be included. For each joint set, the areal distribution, the attitude, and the intensity of jointing (i.e., joint spacing) within the candidate area and site should be presented. Absolute or relative dating of the joint sets should be provided when known.

The mineralogy and age of fillings along joints of any age should be discussed. The possibility that joints may form pathways from the depth of a conceptual design of a repository appropriate to the site to the accessible environment should be discussed. The effect of various joint sets on the fracture permeability of the rock should be provided, or the appropriate sections of Chapter 3, "Hydrology," should be referenced. The relationship of joints to the regional faulting and folding should be described.

The mode of origin of the joints (i.e., extension or shear mechanism) should be discussed. If microcracks are present, describe their geometric and genetic relationships to systematic and nonsystematic joints.

A table listing the various joint sets, in order of age along with their principal characteristics, should be included.

1.3.2.5 Uplift, Tilting, and Subsidence. Uplift, tilting, and subsidence in the candidate area and site, including effects caused by withdrawing or injecting fluids and mining, should be discussed when applicable. This discussion should include the suspected causes of uplift, tilting, and subsidence as well as the rate, magnitude, and areal extent of the uplift, tilting, and subsidence. Quaternary deformation not classified as folds, faults, or joints, e.g., features related to salt tectonics, should also be described.

1.3.2.6 Active Stress Field. The active stress field in the candidate area and site should be discussed. All in situ stress measurements that have been done within the candidate area should be summarized. The data should be tabulated to show the method of stress measurement (e.g., overcoring, the flat jack method), the depth of the measurement, and the actual magnitude and orientation of the principal stresses.

1.3.2.7 Vertical Crustal Movement. Existing data on crustal movement should be summarized and tabulated. Time-dependent gravity and geodetic surveys, geomorphic analyses of landforms, and strain rates from triangulation-trilateration surveys should be summarized.

1.4 Seismology of Candidate Area and Site

The seismic information presented in this section should provide a description of the available seismic data and their relationship to the geologic and tectonic conditions of the candidate area and site. The rationale for using any seismic parameters as bases for any portion of the conceptual design of a repository appropriate to the site should be explained. Information needs for which sufficient data are not currently available should be identified, and plans to obtain the information should be set forth in Part B of the SCP.

1.4.1 Seismology of Candidate Area

This section should include a compilation of all earthquakes in the region surrounding the site that may have an effect on the site. This section should include a description of any extraordinary seismicity such as earthquake swarms, aftershock sequences, or induced seismicity.

1.4.1.1 Seismicity of Candidate Area. Provide a description of the seismic history of the candidate area. The following information should be provided: hypocentral coordinates, origin time, magnitude including scale (ML, MS, mb, mblg, or other), moment, total dislocation, focal mechanism, maximum Modified Mercalli (MM) intensity, and error estimates for these data.

Identify the technique used to locate all epicenters or hypocenters and to determine magnitudes. Differentiate earthquakes on the basis of focal depth, where applicable.

When earthquakes are located on the basis of arrival times of seismic waves, the particular seismic waves should be identified. The local seismic-velocity model used for interpreting and refining travel-time data should be documented.

Revised locations of earthquake epicenters or hypocenters that differ substantially from original locations should be noted. Whenever a revised location is adopted in place of an original location, an explanation for the preference should accompany the revised location. Focal mechanisms that differ significantly from the majority derived for the region should be specifically noted.

Provide a listing of all known historic earthquakes of magnitude greater than 3 or MM intensity greater than IV that have been reported for the candidate area.

Include in separate lists any sequences of earthquakes such as swarms or aftershocks that merit special study and that may fall beyond the criteria stated above. Present a regional scale map of all the listed earthquake epicenters. If they would contribute substantially to a clarification of patterns of seismicity, include cross-sectional views of hypocenters.

1.4.1.2 Relationship of Seismicity to Geologic or Tectonic Characteristics of Candidate Area. Correlate, wherever possible, historic earthquakes to recognized geologic structures or seismo-tectonic zones. Whenever applicable, use the precise locations of hypocenters of small earthquakes to map zones where relief of crustal stress is occurring. Describe stresses derived from focal mechanism solutions and relate them whenever possible to regional stresses that characterize the candidate area.

1.4.1.3 Determination of Earthquake-Generating Potential of Geologic Structures and Seismo-Tectonic Zones Within Candidate Area. Where earthquakes are associated with geologic structure, the maximum potential or credible earthquake that could occur on that structure should be described, taking into account such factors as the type of faulting, fault length, fault displacement, and earthquake history. Where earthquakes are associated with a tectonic zone,

the largest historical earthquake within the zone should be identified. Any trends in the geologic history that could affect the earthquake-generating potential of geologic structures or seismo-tectonic zone within the candidate area should be described.

1.4.1.4 Earthquake-Induced Phenomena Within Candidate Area That May Affect Site. Any earthquake-induced geologic failure such as liquefaction, landsliding, and lurching that has occurred or is characteristic of strong earthquakes in the area should be described completely. Any manner in which such failures could affect the site should be identified.

1.4.1.5 Seismic Risk in Candidate Area. When information is available, estimates of recurrence intervals of maximum probable and credible earthquakes for the candidate area and how these estimates were derived should be discussed. Probabilities of the occurrence of future major earthquakes and their effects on the site derived from past evidence should be determined. Factors that may modify these probabilities in the long term should be described.

1.4.2 Seismology of Site

This section should include a determination of the maximum horizontal and vertical bedrock acceleration due to the most probable maximum potential or credible earthquake that can affect the site. An analysis of the amplification or damping due to the overlying strata should be made for the site both at the surface and at repository depth. The potential for induced seismicity at the site should be assessed (see paragraph 1.4.2.3).

1.4.2.1 Vibratory Ground Motion at Site Resulting from Potential Earthquakes in Area. The conditions describing the occurrence of the earthquake that would produce the largest vibratory ground motion at the site should be defined. If potential earthquakes from different sources would produce maximum ground motion with different dominant frequencies, the conditions describing all such earthquakes should be specified. The ground motion at the site should be evaluated.

1.4.2.2 Characteristics of Seismic Wave Transmission at Site. For each set of conditions describing the occurrence of the maximum potential earthquake, the type of seismic waves producing the maximum ground motion and the significant frequencies should be determined. For each set of conditions, an analysis should be performed to determine the effects of transmission in the site material for the identified seismic wave types at the significant frequencies. Separate analyses should be done for the surface at the site and for the repository depth.

1.4.2.3 Potential for Induced Seismicity Affecting Site. The potential for human activity significantly modifying stresses on the site or in the candidate area that could induce seismicity should be described. These activities include relatively short-term functions such as reservoir impoundment.

1.5 Long-Term Regional Stability with Respect to Tectonic and Geological Processes

Based on Quaternary and present-day active tectonic, geophysical, and geological processes, an assessment of the future stability of the candidate area should be presented with emphasis on the next 10,000 years. Pre-Quaternary structures located within active stress fields should also be assessed. All models, assumptions, parameters, and sensitivity tests to be used for making these assessments should be explicitly stated.

1.6 Subsurface Drilling and Mining

Comprehensive information pertaining to past and present drilling and mining operations should be presented for the candidate area and site. This should include a tabulation of all active and abandoned wells, boreholes, and excavations at the candidate area distinguishing between those wells, boreholes, and excavations that preceded site exploration and those that were part of site exploration. The tabulation should also include such information as the location, depth, diameter, drilling method, casing left in the hole, and method of plugging or sealing. The methods used to investigate the extent of previous drilling and excavation should be discussed. A map showing the location of active and abandoned wells, boreholes, and excavations and the plan view of the conceptual design of a repository appropriate to the site should be provided. Any hydrofractured oil wells should be identified. If the information is available, describe the former use of previous boreholes and the types of testing that were conducted in them. Copies of representative data, logs, and interpretations should be included. Documentation related to calibration procedures and data-massaging techniques should be provided. Interpretation of results should be supported with adequate references. Discuss the adequacy of the historical record in determining the likelihood of undiscovered wells, boreholes, and excavations in the volume of rock and their possible effects on the site. Also include any known boreholes that were lost because of cave-ins or equipment failures.

Provide available information on the effects of the active and abandoned wells, boreholes, and excavations on the principal hydrogeologic units. If sufficient information is available, the presence of potential pathways should be indicated and the net flux and hydraulic gradients created by them should be assessed. (If the information in this paragraph is included in the discussion of hydrology, the appropriate sections of Chapter 3, "Hydrology," may be referenced.)

Provide descriptions, plans, and sections of all active or inactive underground mines within the candidate area, including both conventional mines and in situ extraction types of operations whenever applicable. Describe the kinds of minerals extracted, methods of mineral extraction, the volume of rock removed, and the volume of rock replaced. Include a statement of the present condition of the workings as to subsidence, stability, and flooding.

Provide a description of all active or inactive injection wells within the candidate area. Describe the type and amount of material injected and any known resulting effects, including effects on the local stress field.

1.7 Mineral and Hydrocarbon Resources

Information pertaining to the mineral and hydrocarbon resources of the candidate area and site should be presented in this section.

1.7.1 Mineral Resources

To the extent that information on the mineral resources is available prior to site characterization, the following information should be provided.

The resources of the site should be compared with the resources in comparable areas (those of similar size and geology). Total resources, both identified and undiscovered as defined in the U.S. Geological Survey Bulletin 1450a as revised by USGS Circular 831,* should be included.

Provide a tabulation of the total resources, including (1) the quantity of resources, (2) the cutoff values used in estimating (1), (3) the present gross value of each substance, (4) the present net value of each substance, i.e., the gross value less the costs for exploring, developing, extracting, and marketing the substance, and (5) the unit values of the minerals evaluated in (3) and (4). For each substance, describe the method of assessment.

1.7.2 Hydrocarbon Resources

Describe and locate any past or present oil and gas wells in the candidate area. Discuss the likelihood of future development in the candidate area, including both reserves and potential resources.

*"Principles of the Mineral Classification System of the U.S. Bureau of Mines and the U.S. Geological Survey," U.S.G.S. Bulletin 1450a, 1976. "Principles of a Resource/Reserve Classification for Minerals," USGS Circular 831, 1980.

2. GEOENGINEERING

In this chapter, the mechanical, thermal, and thermomechanical properties of the rock units and the expected parameter ranges that are the basis for the conceptual design of the geologic repository should be presented. Each discussion should include a brief summary of generic information from similar rock units and projects and site-specific information,* if available. The information should be in sufficient detail to (1) permit an understanding of the geomechanical basis of the proposed conceptual design of a repository appropriate to the site (Chapter 6) and (2) support the discussion of design issues in Part B. The discussions should include values or ranges of values for the design parameters used in the conceptual design and should provide the rationale for selecting these preliminary values.

For each of the properties of the rock units, include a discussion of the equipment and procedures used, including their limitations and the errors produced by them. (Equipment and procedures should be referenced to the appropriate standards, e.g., ASTM, where available.) Geologic borehole logs, geologic cross sections, or photographs accumulated during preliminary site exploration activities should be provided when possible to show where tests were conducted or samples were taken. Any measures taken to preserve or restore the in situ chemical and physical environment during site exploration should be described. The anisotropy of the properties should be addressed. If isotropic approximations are assumed, justify that assumption.

2.1 Mechanical Properties of Rock Units - Continua

Present the mechanical properties of the rock units as determined by laboratory tests on intact samples of the potential host rock and of other rock units important for the conceptual design of a repository appropriate to the site and its performance if available. Also present available generic data from similar rock units. Include site-specific information, when available, on elastic and inelastic behavior, time-dependent deformation characteristics, compressive and tensile strength, and effects of heating and fluid pressure on these properties.

2.2 Mechanical Properties of Rock Units - Large Scale

Present the results of any large-scale laboratory and field tests such as plate-bearing tests, chamber tests, flat jacks, Goodman jacks, and convergence tests. ("Large-scale" here means tests of sufficient size to take into account the discontinua (fractures, joints, inhomogeneities, etc.) of the media.) Discuss the relationship of the results of the laboratory tests on intact samples to the results of the large-scale tests. Provide site-specific data, if available, as well as available generic data for similar rock units and environments.

*Site-specific information means information gained from tests done in, or samples taken from, limited borings, surface outcrops, near-surface test facilities, pre-existing tunnels or mines, etc., near the site proposed for characterization. It does not imply that a shaft has been sunk.

2.3 Mechanical Properties of Rock Units - Discontinua

Describe the mechanical properties of discontinua (fractures, joints, bedding planes, inclusions, voids) present in the rock units. Provide site-specific data as well as available generic data from similar rock units and environments. If the information is available, the discussion should include the coefficient of friction, the compressibility of fractures and filling materials, and the effect of heating and changes of pore pressure on the mechanical properties of the joints, fractures, bedding planes, and other discontinua. Discuss the effects of the discontinua on the mechanical properties of the rock mass (e.g., strength and deformation characteristics).

2.4 Thermal and Thermomechanical Properties - Laboratory Results

Present the results of laboratory studies of the thermal properties of the rock units. Provide available site-specific data as well as generic data from similar rock units.

Include discussions on the thermal conductivity, heat capacity, and coefficient of thermal expansion of the rock units.

2.5 Stress Field

Present the stress field data, if available, and list the assumptions used to infer stress from field observation. Also present applicable stress measurements that have been made in the candidate area or at the site. Include a discussion of the expected direction and magnitude of the principal stresses as a function of depth.

2.6 Special Geoengineering Properties

Describe any special thermal, mechanical, thermomechanical, or other properties of the rock units that were considered in developing the conceptual design of a repository appropriate to the site (e.g., brine migration, thermal decrepitation, thermal dewatering). Provide available site-specific data as well as generic data from similar rock units.

2.7 Excavation Characteristics of Rock Mass

Describe excavation investigations that have been conducted within the candidate area, and discuss pertinent excavation experience in similar rock types under similar conditions using various techniques such as controlled blasting and mechanical nonblasting. This discussion should include information on how the investigations were monitored, analyzed, and applied to the conceptual design of a repository appropriate to the site. The discussion should also include an assessment of the potential damages produced by the various techniques and appropriate methods for avoiding or mitigating such damages.

3. HYDROLOGY

Include in this chapter pertinent information gathered on hydrologic conditions of the candidate area and site. Surface and subsurface hydrologic regimes should be addressed. The information should be presented in sufficient detail to (1) describe the hydrology based on available literature and preliminary site exploration activities and (2) provide information to be used to analyze the hydrologic aspects of the planned site characterization program.

3.1 Description of Surface Hydrology

Describe the hydrologic framework of the surface waters of the candidate area and site. Address the location and physical and hydrologic characteristics of surface-water bodies such as streams, lakes, and shore regions influencing the site. Include a description of existing and proposed water control structures, both upstream and downstream, that may influence conditions at the site.

3.2 Floods

3.2.1 Flood History

Provide the date, level, peak discharge, and related information for major historical flood* events in the candidate area. Include stream floods, surges, seiches, tsunami, dam failures, ice jams, floods induced by landslides, and similar events.

Discuss whether the site is flood dry or non-flood dry using procedures presented in ANSI/ANS 2.8 N170-1981.** If procedures other than those presented in ANSI/ANS 2.8 N170-1981 are used, state the reasons and describe the procedures.

Discuss the potential for future flooding of the site. Include long-term changes in the hydrometeorology of the region and the potential for floods induced by maximum glaciation. Describe planned or ongoing studies to thoroughly investigate the potential for future flooding. Include geologic evidence of Pleistocene and Holocene flooding in the assessment of future flood potential.

3.2.2 Flooding Protection

Describe the static and dynamic consequences of all types of flooding that could occur at the candidate area and site. Present the plans and any completed flow analyses needed to ensure that these types of flooding would allow continued integrity of surface and subsurface structures at the site.

*A flood is defined as any abnormally high water stage or overflow from a stream, floodway, lake, or coastal area that results in significantly detrimental effects.

**See American National Standards Institute Standard ANSI/ANS 2.8 N170-1981, "Standards for Determining Design Basis Flooding at Power Reactor Sites." Copies may be obtained from the American Nuclear Society, 555 North Kensington Avenue, La Grange Park, Illinois 60525.

3.3 Locations and Distances to Points of Surface-Water Use

3.3.1 Present Quantity and Quality of Surface Water Extracted

Provide a tabulation of existing surface-water intakes (including collector well systems) downstream of any identified ground-water discharge areas. For each surface-water intake, provide the location, population served, type of intake, and the maximum daily and average quantities of water pumped. Also, the water quality at the intake locations and the type of treatment given to the water before distribution should be discussed.

3.3.2 Projected Surface-Water Uses

Estimate quantities and potential areas of water use for the region into the future. Base the projections on expected growth rate of the region; industries likely to develop in the future because of location, climate, or natural resources; and probable changes in the technology or economic requirements. Do not base the projections on extrapolations of historical data alone. Also locate possible points of withdrawal for any potential future water users that have been identified.

3.4 Chemical Composition of Adjacent Watercourses

Describe the chemical composition of adjacent bodies of water that could potentially be affected by releases from the facility. The chemical data should be sufficient to determine the salt seep or salt discharge rates into drainage basins for dissolution studies. This description should include measured baseline data derived from historical records and onsite monitoring programs prior to site characterization activities.

The seasonal cycles of physical and chemical limnological parameters should be provided. Additionally, information that describes the bottom and shoreline configuration, sedimentation rates (suspended and bed load), sedimentation graduation analysis, and distribution (sorption) coefficients should be included.

3.5 Surface-Water/Ground-Water Disposition of Releases

Identify, define, and map all known sources of ground-water discharge within the candidate area, including springs, seeps, and wells. Provide an estimate of the rate of ground-water discharge at these points. If the discharge is through a stream channel or lake bed, the discharge per square meter of lake bed or linear meter of stream channel should be estimated. Provide the bases for the discharge estimates such as base flow measurements, water balance calculations, and aquifer hydraulics.

Discuss the potential for contamination of surface waters as a result of either surface or subterranean releases. Any surface discharge areas (springs and seeps) of aquifers that could become contaminated by releases from the subsurface operations during site characterization should be identified.

3.6 Regional Hydrologic Reconnaissance of Candidate Area and Site

Describe the regional hydrogeologic framework and regional ground-water flow systems and their boundaries.*

3.6.1 Hydrogeologic Units

Present a hydrogeologic column of the region in a form as detailed as the information allows. Include the principal hydrogeologic units (includes both confining units and aquifers), their stratigraphic relationships, lithology, generalized potentiometric levels for a given time and location, and hydrologic characteristics. The terminology should be consistent with the terminology used in the regional stratigraphic column presented in Section 1.2. A hydrogeologic map of the candidate area should be presented indicating areal extent of the regional hydrogeologic units and unit interfaces and data points.** Cross sections should be provided where appropriate.

3.6.2 Relationships Among Hydrogeologic Units

Describe the relationships among the regional hydrogeologic units. The principal relationships sought are potentiometric levels, recharge-discharge and leakage, hydrochemical facies, hydrologic interconnection between units (fractures, faults, etc.) and ground-water residence times. References should be made to the hydrogeologic map and to the cross sections presented in Section 3.6.1.

3.6.3 Potentiometric Level

Define the time history and areal distribution of measured potentiometric levels of each principal hydrogeologic unit. The method of presenting the data can include hydrographs, potentiometric contour maps, and graphs to identify the characteristic fluctuations resulting from the various types of recharge-discharge (i.e., seasonal precipitation and evaporation fluctuations, seasonal pumping variations, seasonal response to surface-water bodies, etc.). Potentiometric surface maps should include such information as the location of the monitoring wells, hydrogeologic unit boundaries, surface-water bodies, and specific well information (i.e., perforation interval and elevations, total depth history, casing, method of well completion, etc.).

3.6.4 Hydraulic Characteristics of Principal Hydrogeologic Units

For each of the principal hydrogeologic units, provide the ranges, mean values, and methods for determining the principal hydraulic characteristics such as horizontal and vertical hydraulic conductivity, storage coefficient, effective porosity, and saturated thickness. Also include a discussion of the appropriateness of assuming Darcian flow conditions in the various hydrogeologic units.

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*Definitions of ground-water terminology used in this chapter are consistent with U.S. Geological Survey Water Supply Paper No. 1988, "Definitions of Selected Ground-Water Terms - Revisions and Conceptual Refinements" (1972).

**Use, where practicable, internationally recognized map symbols (UNESCO, International Legend for Hydrologic Maps, Paris, France, 1970).

3.7 Regional Ground-Water Flow System

Provide detailed information on the regional ground-water flow system, including identification of recharge and discharge areas, principal ground-water flow paths, and ground-water ages based on isotopic hydrochemistry.

3.7.1 Identification of Recharge and Discharge Areas

Identify the areas and modes of recharge and discharge, residence times of the ground water, and the bulk rates of ground-water flow for the specific hydrogeologic units. Also include surface- and ground-water interrelationships. Present the information on hydrogeologic maps developed for the region.

3.7.2 Principal Ground-Water Flow Paths

Describe the principal ground-water flow paths to the accessible environment. Include in this description estimates of the associated ground-water fluxes and travel times to the accessible environment, with the bases for such estimates. Use cross sections and maps (flow nets or potentiometric maps) to indicate the principal ground-water flow paths.

3.7.3 Isotopic and Regional Hydrochemistry

Describe the results of any investigations of the isotopic composition of ground-water samples. Include stable isotopes, e.g., D/H, O^{16}/O^{18}, and unstable isotopes, e.g., C^{14}, H^3, Cl^{36}. Discuss the implication of the isotopic data concerning the age of the ground water, relative degree of circulation within the hydrogeologic unit, and areas and modes of recharge to the hydrogeologic units.

Describe the results of any studies of the regional hydrochemical zones. The major ions of interest are Na^+, Ca^+, Mg^+, Cl^-, Fe, Mn^{++}, HCO_3^-, CO_3^{2-}, and SO_4^{2-}. The individual hydrochemical zones should be presented in graphic form showing the relationship among the principal ions. Each zone should also be delimited by its pH, Eh, total dissolved solids (TDS), organic carbon, organic complexes (fulvic and humic acids), and aforementioned principal ions.* The major dissolved gases such as carbon dioxide, methane, and hydrogen sulfide should be included. Information on ambient ground-water temperature should also be provided. If any of the information in the section is not currently available, discuss any plans for obtaining it within the context of the site characterization program in Part B of the SCP.

3.7.4 Paleohydrology

Describe the hydrologic conditions that have occurred during the Quaternary Period that have significantly differed from present conditions. Each major episode should be discussed both as to its effect on the ground-water flow regime and its likelihood of recurrence over the next 10,000 years.

*Field and laboratory analysis methods should conform to those in National Handbook of Recommended Methods for Water Data Acquisition, Chapter 5, Federal Interagency Committee on Water Data, Office of Water Data Coordination, U.S. Geological Survey, Reston, Virginia, 1977-1978.

3.8 Ground-Water Uses

Identify the principal regional ground-water uses, including locations, rates, typical well construction, and hydrogeologic unit source. Include irrigation, industrial, municipal, domestic livestock, and energy resource development uses. Identify areas of large ground-water pumping or injection on the regional hydrogeologic map. Include the extent of depression or impression cones on the potentiometric surfaces.

3.8.1 Regional Ground-Water Aquifers Used for Human Activities

Identify the specific aquifer units that provide the sources for the ground-water uses identified in Section 3.8. Also present the relationship between ground-water use and aquifer storage and recharge to identify areas of stress on the aquifer and mining of the ground-water resource.

3.8.2 Regional Ground-Water Management Plans

Identify the regional ground-water management agencies and their programs. Also provide an assessment, using this information, of regional ground-water projections for the foreseeable future, preferably the next 50- to 100-year period. Include ground-water use, potentiometric level changes, and hydrochemical changes.

3.9 Site Hydrogeologic System

Describe the site hydrogeologic systems to the extent that available information will permit. This section is structured for situations where saturated flow conditions dominate. However, additional information requirements are specified for those sites located in unsaturated conditions.

3.9.1 Baseline Monitoring

Provide information gathered from the baseline monitoring* program such as potentiometric levels and hydrochemistry of the principal hydrogeologic units.

3.9.1.1 Monitoring Network. Provide specifications and designs (i.e., locations, elevations of screens and measuring points, elevations of seals), selection process for choosing location and depth of data collection systems, hydrogeologic units being monitored, method and frequency of measurement, and method of hydrochemical sampling for the monitoring network used in establishing the baseline monitoring program.

3.9.1.2 Potentiometric Levels. Provide representative hydrographs and potentiometric surface maps for each principal hydrogeologic unit. The hydrographs should include precipitation, surface-water levels, and rates of ground-water pumpage where appropriate. Based on this information, provide completed

*Baseline monitoring means the establishment and operation of an engineered surveillance system for continuous measurement and recording of existing ground-water conditions that will serve as an historical data base for future observational comparisons.

assessment for the potential for long-term or significant short-term changes in the water levels, and indicate them on hydrographs and potentiometric maps.

3.9.1.3 Hydrochemistry. Provide the previously gathered information on the hydrochemistry of the principal hydrogeologic units. In characterizing each unit, identify the major and trace inorganic constituents, organic components, dissolved gases, Eh-pH values, temperatures, density of the fluid(s), and naturally occurring radioisotopes (see Section 4.1). In addition, at sites where human activity may have introduced radioactivity into the ground water, analysis should be done for those radioisotopes that are known or suspected to have been added to the system. Using this information, provide assessments of temporal and spatial variations of the hydrochemistry.

3.9.2 Hydraulic Characteristics

Information on the vertical and horizontal hydraulic characteristics for each principal hydrogeologic unit and a discussion of statistical parameters and values should be provided. The methods of determination, range, and mean values should also be provided. The information should be grouped into separate sections for each hydrogeologic unit and should include the following characteristics:

1. Intrinsic Permeability. Indicate whether the intrinsic permeability is developed by secondary processes such as fracturing, weathering, dissolution, or degassing of igneous rocks and the extent to which Darcian flow can be assumed.

2.a. Saturated Flow Hydraulic Conductivity and Transmissivity. Indicate the representative volume applicable and the saturated thicknesses assumed, or

b. Unsaturated Flow Hydraulic Conductivity. Indicate the unsaturated zone properties, including soil moisture curve relationships.

3. Total and Effective Porosity. Indicate the nature of the pore space, i.e., interstitial, fractured, or solutioning, and distinguish primary and secondary porosity.

4.a. Saturated Flow Storage Coefficient. Provide storage coefficients for confined and unconfined aquifers.

b. Unsaturated Flow Storage Coefficient. Indicate the moisture content for the unsaturated zone, and relate it to hydraulic potential and hydraulic conductivity (such as hydraulic conductivity versus capillary pressure and moisture content versus capillary pressure).

3.9.3 Ground-Water Flow System

Describe the ground-water flow system using the previously described hydraulic characteristics, and identify the accessible environment and credible pathways.

3.9.3.1 Accessible Environment and Credible Pathways. Identify the accessible environment associated with the conceptual design of a repository appropriate to the site. The credible pathways for ground-water transport from the

conceptual design of a repository appropriate to the site to the accessible environment should also be identified. The basis for designating the boundary of the controlled area should be included.

3.9.3.2 Potentiometric Levels and Head Relationships. Provide a synthesis and analysis of potentiometric levels and head relationships as described in paragraph 3.6.3. Include hydraulic gradients, flow directions, and potential for variations. For the unsaturated zone, provide similar information on negative potential, flow characteristics, and seepage fluxes.

3.9.3.3 Recharge-Discharge and Leakage. Provide information on completed investigations on the location and rates of recharge-discharge and leakage for the principal hydrogeologic units. Fully document these investigations. Where appropriate, constant head, no-flow, and constant flux boundary conditions should be identified and indicated on the appropriate hydrogeologic map. Provide plans to use the regional and site hydrochemical analyses to identify or verify the location of recharge, discharge, and mixing zones.

3.9.3.4 Unsaturated Zone Relationships. Identify the spatial and temporal extent of the unsaturated zone, and indicate the principal mode of recharge. Describe the temporal aspects and presence of perched water tables, their confining units, water flow rates, and flow direction. Indicate the local flux rates for the unsaturated units to the regional water table or surface-water bodies. Identify the credible pathways, including the potential for vapor transport.

3.9.4 Ground-Water Velocity and Travel Time

Describe the method of determination and the ranges of values for the average interstitial velocities for Darcian flow conditions or the maximum velocities for fractured flow of the principal hydrogeologic units based on the representative elementary volume. Using the information gathered on credible pathways, indicate the expected range of advective travel times from the conceptual design of a repository appropriate to the site to the accessible environment.

3.9.4.1 Radionuclide Transport Factors. Provide information on the methods and the results of investigations performed to determine the factors influencing radionuclide transport for each hydrogeologic unit occurring in the credible pathway. The investigations and methods of analysis should take into consideration the temperature, viscosity, water chemistry, retardation, and oxidation-reduction potential within the hydrogeologic units and the projected thermal flux due to the emplaced waste.

3.9.4.2 Geothermal Gradient and Thermal Convective Component. Identify the existing geothermal gradient, and assess the effect of the thermal convective component introduced by the emplaced waste on the ground-water transport.

3.9.5 Hydrochemistry and Ground-Water Age

Describe the results of completed investigations of the hydrochemistry and ground-water age of each principal hydrogeologic unit. Include the tests and method of sampling performed and to be performed for the hydrochemical investigation.

Identify the isotopes (i.e., C^{14}, H^3, O^{16}/O^{18}, D/H, Cl^{36}) used for ground-water age determinations, including the field and laboratory techniques used, the range of values, and an error analysis of the results.

3.9.6 Monitoring and Verification

Provide information on the specific monitoring and verification programs, including their spatial and temporal distribution, implemented for the hydrologic system associated with the geologic repository.

3.9.6.1 Baseline Condition Changes. Describe aspects of the general monitoring program that augment the baseline monitoring program and that contribute to descriptions and evaluations of changes in baseline conditions.

3.9.6.2 Well Construction, Development, and Completion. Describe well construction and development techniques. Include such details as locations; elevations of screens and measuring data; hydrogeologic units encountered; method of development; types and locations of borehole seals, casing, and screen materials; mode of drilling; and method and schedule of development.

3.9.6.3 Monitoring Methods. Describe the method of sampling and/or surveillance used. Provide information on the indirect methods of sampling such as geophysical techniques and TV surveillance. Also provide information on the direct methods of sampling such as water sampling, potentiometric level readings, and pressure testing. Indicate the hydrogeologic information collected using each monitoring method.

3.9.7 Local Ground-Water Users

Identify all the local ground-water users, including locations, rates, typical well construction, and hydrogeologic unit source. Include irrigation, industrial, municipal, domestic, livestock, and energy resource development users. Determine what effect, if any, the local ground-water and surface-water users have on the site's ground-water flow system.

3.9.8 Paleohydrology

Describe the hydrogeologic conditions that have occurred during the Quaternary Period that have significantly differed from present conditions. Each major episode should be discussed both as to its effect on the ground-water flow regime and its likelihood of recurrence over the next 10,000 years.

4. GEOCHEMISTRY

In this chapter, present pertinent descriptions of the geochemical properties of the rocks, minerals, sediments, and water of the candidate area and site. Include the anticipated radionuclide transport mechanisms (i.e., liquid water, vapor, gas) from the canister to the accessible environment and expected geochemical reactions that have influenced the conceptual design of a repository appropriate to the site. Also include generic data from similar rock types and site-specific information, if available. The information should be presented in sufficient detail to (1) permit an understanding of the geochemical factors of the candidate area and site based on available literature and site-screening studies and (2) support the planned site characterization program.

For each of the following sections, include the rationale for the values chosen. For natural variables (e.g., rock compositions and ground-water chemistry), indicate expected ranges of values and by what process these were assumed. For engineering variables (e.g., composition of backfill, waste form, canister, temperature, and pressure), indicate why these particular values were assumed and what is the reasonable range of expected values. For chemical and geochemical reactions (e.g., any of the reactions among the waste, water, vapor, gas, rock, barrier, canister), indicate the rationale for the identification of these reactions (e.g., theoretical, laboratory experimental, observed in nature) and to what extent the nature of the reactions would be expected to change because of changing conditions at the site (e.g., changes in solubility of constituents in ground water resulting from heating the ground water).

4.1 Host Rock Geochemistry

For rocks and fracture fill materials along credible pathways to the accessible environment, describe the petrology and mineralogy of the rocks and material in the fractures. Describe the inferred and measured distribution and abundance of mineral phases that will affect radionuclide migration, and identify inferred and measured mineral assemblages and amorphous components that buffer pH and Eh of ground water. This description should consider (1) baseline conditions, (2) the period prior to closure, (3) the period between closure and release, (4) release and (5) transport.

For the proposed host rock unit and other rock units along credible pathways to the accessible environment, provide the following information when available.

1. Supporting data and analyses determining the geochemical baseline site conditions. To the extent reasonable in light of the geologic record, it should be assumed that processes operating in the geologic setting during the Quaternary Period continue to operate. For example:

    a. Petrology, mineralogy,
    b. Major, minor, and trace-element composition of ground water, including organic and inorganic species, dissolved and suspended (i.e., colloids),
    c. Ionic strength of ground water,
    d. Complexing agents (organic and inorganic),

e. pH,
f. Eh (measured and calculated), dissolved oxygen, redox couples (i.e., Fe^{+2}/Fe^{+3}),
g. Temperature,
h. Pressure,
i. Gas composition,
j. Sorption-desorption isotherms, including those for fracture filling,
k. Sorption capacity, and
l. Background radioactivity.

2. Supporting data and analyses defining changes in baseline site conditions expected under repository operating and postclosure conditions through a period of 10,000 years.* For example, see 1 for baseline conditions.

3. Supporting data and analyses defining the geochemical reaction mechanisms under repository operating and postclosure conditions (including kinetic effects) affecting the transport of radionuclides through a period of 10,000 years.* For example:

a. Precipitation/dissolution,
b. Ion exchange,
c. Chemical substitution,
d. Isotopic exchanges,
e. Diffusion into pores,
f. Diffusion into solids,
g. Colloid/pseudocolloid production,
h. Gamma and alpha radiolysis,
i. Speciation, and
j. Complexation (organic/inorganic).

Discuss the methods used to obtain the data as well as the quality assurance programs applied to data collection. Also, discuss the validation/verification of the data and analyses and the appropriateness of the geochemical data that have been and will be collected for use with expected performance assessment methods. If information on any (or all) of these geochemical parameters is not available at the time the SCP is submitted, describe the proposed plans for obtaining this information during site characterization. (The proposed plans may be described in Part B.)

4.2 Chemistry of Waste, Barriers, and Environment of a Conceptual Design Repository Appropriate to Site

Describe expected interactions among the waste form, engineered barriers, and environment of a conceptual design of a repository appropriate to the site. Include analyses of generic interactions and, if available, include analyses of interactions of proposed specific waste forms and engineered barriers for the site.

*To the extent reasonable in light of the geologic record, it must be assumed that 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.

Describe the expected (1) chemical composition and form of the waste, (2) solubility of the waste form in ground water under varying expected environmental conditions (e.g., temperature, oxidation states), and (3) species released by the leaching of the waste form under expected conditions.

Describe the expected chemical and mineralogical composition of any barriers, solubility of these barriers under varying anticipated physico-chemical conditions, any changes in speciation imposed on radionuclides released from the waste, and speciation of wastes crossing the engineered barrier/natural geological systems boundary.

Describe the expected interactions of the waste, water, vapor, gas, and rock. Include (1) hydrothermal alteration of the proposed host rock during the thermal pulse, (2) changes in the chemistry of the ground water in the proposed host rock during the thermal pulse, and (3) the effect of changes of mineralogy and ground water on the radionuclide migration.

4.3 Natural Analogs

Provide pertinent data, analyses, and current level of assessment of natural geochemical analogs to the site. Provide a basis for comparing and contrasting the analog environment with the site.

Describe any field tests from other sites that may be useful in interpreting expected results obtained from this site during site characterization.

4.4 Geochemical Stability

Describe the expected geochemical stability of the site. Include (1) potential human influences (i.e., solution mining, injection disposal, ground-water withdrawal, ground-water mining) and (2) natural changes due to climatic variation.

5. CLIMATOLOGY AND METEOROLOGY

Provide a description of the climatology and meteorology of the candidate area and site. An analysis of paleoclimatic conditions should provide an assessment of the climatic changes that might occur in the future, based on evaluations of the past and present climatic conditions. Paleoclimatic analysis should include at least the complete climatic spectrum ranging from maximum glacial to maximum interglacial conditions. Sources of the information and data provided should be referenced. Identify those areas where sufficient data or information are presently not available.

5.1 Recent Climate and Meteorology

A climatological and meteorological description should be provided for the candidate area and site.

5.1.1 Climate

The general climate should be described with respect to types of air masses, synoptic features and frontal systems, and general airflow patterns and relationships between synoptic-scale atmospheric processes and local (site) meteorological conditions. Climatological characteristics attributable to the terrain should be identified. Data should be provided in sufficient detail to indicate impacts on the conceptual design and potential operation of a repository at the site.

All information should be fully documented and should be based on data for the most recent 30-year record period. Sources of such information could include National Oceanic and Atmospheric Administration (NOAA) facilities such as the National Climatic Center (NCC) and the National Weather Service (NWS) stations; other government facilities (e.g., military stations); and private organizations such as universities that have maintained quality-controlled data collection programs. The validity of the information provided, with respect to representation of the conditions at and near the site, should be substantiated.

5.1.2 Local and Regional Meteorology

Plans for obtaining sufficient meteorological information to adequately characterize atmospheric dispersion processes (i.e., airflow trajectories, atmospheric stability conditions, depletion and deposition characteristics) within the candidate area should be provided.

5.1.3 Site Meteorological Measurement Program

The meteorological measurement program to be conducted to develop local data and programs that will be used to estimate offsite concentrations of effluents released during site characterization should be described. The information provided should include measurements made, locations and elevations of measurements, descriptions of the instruments used, instrument performance specifications, calibration and maintenance procedures, and data analyses procedures.

5.2 Long-Term Climatic Assessment

An analysis of paleoclimatic conditions at the candidate area and the site should be provided. Based on this analysis and on recent climatic characteristics of the candidate area, an assessment of the magnitude and rate of climatic changes that might be expected to occur in the future should be provided. The information should be presented in sufficient detail to indicate impacts on long-term isolation of the waste.

5.2.1 Paleoclimatology

Provide an analysis of the Quaternary paleoclimatology of the candidate area and the site, including atmospheric, hydrospheric, and cryospheric aspects of the successive climatic regimes, in the context of determining the magnitude of the climatic changes and the rates at which the changes occurred. Changes in precipitation regimes, locations of potential aquifer recharge areas, glaciated areas, and windflow patterns should be identified. Geological, biological, and ecological evidence to support the analysis should be provided. Information should also be provided on the size (areal extent and thicknesses) of any glaciers and on accumulation and ablation rates. The impacts of any glaciers on precipitation regimes and windflow patterns should be discussed. Relationships between air temperatures and regional precipitation, in relationship to the water balance of the area, should also be discussed.

Sources of all information should be provided. The validity and applicability of the information provided, with respect to the representation of conditions at and near the site, should be substantiated.

5.2.2 Future Climatic Variation

An estimate of the potential impact of climatic change on precipitation patterns, windflow regimes, the cryosphere, and sea levels should be discussed.

Based on the reconstruction of the paleoclimate and the recent climate, long-term estimates of the following should be provided:

1. Potential maximum and minimum changes and rates of change in precipitation and air temperature from the present that could be expected to occur,

2. Potential regional windflow and precipitation patterns that may evolve in the future as a result of climatic and geologic changes,

3. The potential for glaciation, including estimates of times of onset of glaciation and lengths and severity of glacial regimes in the site area, and

4. Future fluctuations in sea levels and cryosphere due to climatic changes.

All procedures, including models, used in the climatic extrapolations should be identified, as should all assumptions and areas where insufficient data make extrapolations questionable. All assumptions and areas where there are not sufficient data to make reasonable extrapolations should be identified.

6. CONCEPTUAL DESIGN OF A REPOSITORY

Provisions for the inclusion in the SCP of a conceptual design of a repository* appropriate to the named site are set forth in paragraph 60.17(c) of 10 CFR Part 60. Information on the conceptual design of a repository is needed to allow an assessment of the site characterization program since a substantial amount of the information generated during site characterization will directly relate to the progressive development of a repository design for the site. It is recognized that the conceptual design repository presented in the SCP will be preliminary in nature and may be modified or refined as a result of site characterization activities. Consequently, it is necessary to know at the SCP stage which portions of the conceptual design of a repository are based on results developed during preliminary site exploration activities and which portions are based on assumed parametric values or anticipated site conditions. All assumptions of parametric values (e.g., in situ stress field) and site conditions (e.g., ground-water hydrology) should be clearly documented in the SCP. Assumptions that will be confirmed or refined during site characterization should be noted. To the extent possible, the design bases, design assumptions, preliminary design criteria, and preliminary analyses that have been performed to develop the conceptual design of a repository should be stated, and the structures, systems, and components important to safety should be identified. Features of the design that allow for the retrieval option should be identified.

Information on a design of a repository must be provided in sufficient detail to allow the NRC to make a determination concerning the completeness and relevancy of planned site characterization activities. The types of information needed by NRC include information on the design and on the site to show that the site and design meet the performance requirements of 10 CFR Part 60. Specifically, there must be sufficient information provided to allow the NRC to determine whether licensing information requirements are addressed by the site characterization plans and whether the right kinds and amounts of testing are planned to fulfill those licensing requirements.

6.1 Design of Underground Openings

Provide the general layout and design of proposed subsurface openings in plan and cross section, and show their relationship to proposed plans for in situ testing at depth and to known or inferred geologic and hydrologic conditions of the site. If known, identify proposed locations of shafts and their relationship to the proposed plan for in situ testing at depth and known or inferred subsurface conditions. Discuss shaft stability based on inferred subsurface rock stresses and ground-water conditions and their relationship to the proposed test shaft(s). Provide the basis used in determining the proposed sizing, shape, and orientation of the major subsurface openings. Include

*As used in this guide, the conceptual design of a repository means a design of a repository appropriate to the named site in sufficient detail to allow assessment of the site characterization program with respect to investigative activities that address the ability of the site to host a repository and isolate radioactive waste or that may affect such ability.

discussions of those considerations given to ground-water conditions, thermal output, the natural and thermally induced stress field, rock creep where applicable, and the need for ventilation. Identify and discuss separately any design limitations due to factors not directly related to waste isolation but to the constructability or operability of the repository. Include factors such as minimum space required for emplacement of the waste, layout requirements for separation and control of excavation and waste emplacement operations, ventilation requirements, and worker safety considerations.

6.2 Backfill

Describe the proposed characteristics and functions of the backfill in the conceptual design of a repository. Identify any proposed backfill materials being considered for use at the site. Provide the mechanical properties of the proposed backfill that are critical for the site and design (use ASTM or other applicable standards, as appropriate). Discuss the relationship between the mechanical properties of the proposed backfill and the expected conditions at the site (e.g., temperature, moisture, stress, radiation). Describe the geochemical characteristics of the backfill materials, as well as the anticipated chemical interactions among the waste package, backfill, ground water, and host rock under assumed waste emplacement conditions. Identify the measured or inferred material and site parameters used to estimate those reactions. Describe any effect of the backfill on retrieval procedures. Describe any effects of radiation on the backfill or its interactions. (The geochemical discussion here should be in sufficient detail to describe the geochemical role of the backfill at the site. The full descriptions of the geochemical investigations and the nature of backfill, waste form, package, rock, and ground-water interactions should be provided in Chapters 4, "Geochemistry," or 7, "Waste Form and Package.")

6.3 Strength and Deformability of Rock Mass

Provide preliminary design values used for the mechanical properties of the rock, including elastic and inelastic behavior of the rock mass, the thermomechanical behavior of the rock mass, and the mechanical behavior of rock discontinuities (e.g., joints, bedding planes, shear zones). Describe how they were determined. Describe any effects of radiation on these properties. (The rock mechanics information should be presented here in sufficient detail to describe the relationship of the rock properties to the design. The full description of the rock mechanics background should be presented in Chapter 2, "Geoengineering.") Describe how these values for the mechanical and thermomechanical behavior of the rock were used in developing the conceptual design of a repository. Present the results of model studies used in developing the conceptual design of a repository appropriate to the site.

6.4 Sealing of Shafts, Boreholes, and Underground Openings

Describe the proposed treatment of the disturbed section of rock around openings and excavated surfaces. Describe proposed design measures to control ground-water movement into the facility. Provide laboratory and field data when available and inferred site conditions on which the selection of the treatment measures was based. Describe the proposed design for the sealing of

boreholes and shafts. Provide laboratory and field data and inferred site conditions on which the design was based. Provide the mechanical, chemical, and hydrologic properties of proposed sealing materials.

6.5 Construction

Describe construction techniques being considered for potential repository development at the site. Describe in detail any known or inferred site conditions requiring specialized construction techniques. Describe planned actions to be taken so that construction of exploratory workings at the site would not compromise the integrity of the site.

Describe methods under consideration for breaking and removing rock during construction. Assess the potential impacts of construction on fracturing, and note any special precautions needed to minimize propagation of fractures that could be potential pathways, taking into consideration the inferred rock conditions at the site proposed for characterization. Describe the geotechnical factors expected to bear on the suitability of proposed excavation techniques and their relationship to any information obtained during exploratory drilling. Mechanical excavation methods, controlled blasting, or other measures proposed to be used in the construction of underground openings should be described and related to known or inferred rock conditions. (The full description of excavation investigations should be given in Chapter 2, "Geoengineering.") Describe temporary or permanent rock reinforcement and rock support structures proposed and their relationship to the basis of the conceptual design. The methods planned to be used to control, collect, and dispose of ground water during excavation and the relationship of the planned methods to ground-water information obtained from exploratory investigations should be described. Describe in detail any special equipment needed or any equipment preferred.

6.6 Design of Surface Facilities

Provide a description of properties of surface materials and foundation soil or rock considered in the design of structural foundations for surface facilities. Describe expected or known soil and rock conditions and the depth and quality of foundation soil or rock. Discuss any known or inferred foundation problems. Also, describe sources of water for construction and operation of the proposed facilities.

6.7 Repository System Component Performance Goals

Provide preliminary numerical values for the performance goals for the repository system components, i.e., specify the provisional allocation of performance goals to individual components of both the natural and engineered repository systems to ensure that the repository as a whole meets overall performance goals. Performance goals for the repository system components are necessary to enable evaluation of whether or not the planned testing and characterization of these components wll be adequate to indicate that the necessary performance can be achieved. Without establishing early in the repository design process specific performance goals for system components, there would be no basis for establishing the precision and accuracy required in test results or the performance levels to be verified by the testing or even the types of testing necessary. Thus, preliminary performance goals are an essential foundation that must underlie any sound site characterization program.

7. WASTE FORM AND PACKAGE

Evaluate the principal candidate waste forms and packages that may be considered appropriate for the site, and describe how the range of environments anticipated at the site and the resulting design limits would affect these waste forms and packages. To the extent that the information is available prior to site characterization, describe and compare alternative waste forms and packages being considered and their development programs. Provide a basis for evaluating the adequacy of the information to be produced in the site characterization program.

7.1 Description

Describe the candidate waste forms (including physical form and mechanical properties, chemical form and properties, radionuclide inventory, thermal output, expected temperatures, and radiation released) and waste packages (including types of packaging and their properties, container size and shape, and the weight, volume, and number of the containers to be emplaced).

7.2 Design Concepts

Describe the waste form and package design concepts considered appropriate for the site and the conceptual design of a repository appropriate to the site. Discuss the independent barriers within the waste package and estimates, if available, of the reliability of these individual barriers.

7.3 Research and Development

Describe the status of research and development on appropriate waste forms and packages as it relates to characterization of the site, including research planned or under way to evaluate the performance of such waste forms and packages.

7.4 Emplacement Environment

If candidate waste packages and materials have been identified, describe the type of environment into which the waste form and packaging may be placed. Include upper bounds that could be expected for:

1. Chemical conditions and processes within and between the waste package and its environment that could compromise or enhance the ability of the waste package to support the performance objectives. Include appropriate thermodynamic equilibria, oxidation/reduction reactions, corrosion, electrochemical reactions, leaching, dissolution, and gas generation.

2. Physical conditions and processes within and between the waste package and its environment that could compromise or enhance the ability of the waste package to support the performance objectives. Include thermal effects, mechanical strength, and mechanical stress.

3. Nuclear conditions and processes within and between the waste package and its environment that could compromise or enhance the ability of the

waste package to support the performance objectives. Include radiolysis, potential radiation damage, and potential criticality.

7.5 Alternative Waste Forms and Waste Packages

Sufficient information about alternative waste forms and waste packages should be provided to show full integration of the criteria and decision processes for site selection with those for waste form and waste package selection.

PART B

STANDARD FORMAT AND CONTENT GUIDANCE FOR PRESENTING THE SITE CHARACTERIZATION PROGRAM

While Part A of the Standard Format provides guidance on the presentation of what is already known about a site, Part B deals with what DOE plans to do in site characterization.

Part B of the Standard Format specifies that the SCP should:

1. Identify issues (questions about a site that are critical to making the findings required by 10 CFR Part 60 for construction authorization);

2. Specify information needs required to make findings on unresolved issues; and

3. Describe the planned methods of data acquisition synthesis and analysis to meet information needs for unresolved issues.

There should be a brief evaluation of the significant options available for resolving issues and for methods of testing and analysis that will reduce the limitations and uncertainties of the tests, methods, data, and interpretations of data. Both the surface testing and the in situ at-depth testing aspects of the planned site characterization program should be included.

The SCP will primarily be evaluated according to the completeness of Part B, its most critical part.

In developing Part B of the SCP, DOE should ensure that attention is focused on those aspects of siting, development of waste form and packaging, and conceptual design of a repository that will require the most effort in the site characterization program. While the SCP must be complete in developing the issues of site characterization, it is important--particularly in initial planning phases--that those issues considered critical or most important be identified and given highest priority in the site characterization plan.

The NRC encourages early consultation to identify issues and resolve them prior to the license application to the extent practicable. The Nuclear Waste Policy Act requires an update of the SCP every six months so it can identify new concerns and discuss which issues have been resolved.

8. SITE CHARACTERIZATION PROGRAM

This chapter should provide the rationale behind the proposed site characterization program and should describe in detail the program of exploration and testing to be conducted during site characterization. The description of the site characterization program at the named site should include (1) the issues to be resolved and information to be acquired during site characterization, (2) the tests and experiments to be performed, (3) schedule, sequence, and duration of testing and data analyses, (4) the extent of planned excavation and in situ at-depth testing, (5) elements of the conceptual design of a repository appropriate to the site relevant to data acquisition, analyses, and scheduling, (6) key milestones against which the progress of site characterization can be measured, (7) provisions to control any adverse safety-related impacts from site characterization activities that are important to safety or that are important to waste isolation, and (8) the quality assurance methods to be used in data acquisition and analysis. The decision points at which the direction of the site characterization program might be changed if warranted by the results obtained should also be included.

This chapter should provide information about the planned tests at a level of detail sufficient to enable determination of whether adequate information for licensing will be produced. It should present definitive descriptions of the parameters to be controlled and measured in planned tests or analyses, showing how the tests adequately bound the range of potential limiting conditions that are important to performance of that aspect of the repository being investigated.

In addition to questioning the relevance and completeness of data supplied in the license application, the licensing process must explicitly address the question of whether or not data are of adequate quality so that licensing determinations can be made with reasonable confidence. The quality of data is virtually determined by the specific data-gathering methods and procedures that are used. It is therefore important that specific methods to be used in data gathering and in the site characterization program be the subject of prelicensing consultation between DOE and NRC.

The need for specific information stems from the complex nature of the questions being addressed in the site characterization program. Given the large numbers of variables that can control the nature and rate of significant processes important to site and engineered system performance and the varying conditions that are likely to exist throughout the performance period, a very selective bounding approach to investigations may be useful. Because any single laboratory or field test constitutes an extremely large oversimplification of actual conditions, a careful and clearly documented strategy that identifies the approach to be taken and factors to be considered in planning specific tests is crucial. Because a large judgmental factor will be involved in the identification of specific experiments to be run, the experimental design and strategy should be clearly documented so that it can be reviewed by the NRC staff and other interested parties.

The depth of information provided should consider the need for flexibility to account for the exploratory, developing nature of the investigations. The

initial investigation steps may need to be complete before a full program can be developed. The relative importance of various aspects of the program will change as investigations proceed. A phased approach to testing is necessary. Flexibility is required not only to make fine adjustments in the investigations on a particular subsystem or technical program area but also to make major shifts in the overall program based on the results of ongoing system performance assessments. The relative priorities among the investigations of the subsystems will change as data are gathered, analyzed, and evaluated. Thus, plans may be better defined and more detailed for early phases of site characterization and less detailed for later phases.

However, for testing currently being conducted or planned as the first stage of future investigations, definitive plans must be documented in detail. These plans need not be presented in the SCP itself. They may more appropriately be contained in reference documents and technical program test plans that are made available along with the SCP.

8.1 Rationale for Planned Site Characterization Program

This section should provide the rationale for the planned site characterization program. This rationale should include a summary discussion of (1) the types of information to be obtained during site characterization, (2) why the information is needed, and (3) whether the information will provide confirmatory or supplemental data and analyses to existing data and analyses or whether the information will be acquired in areas not addressed during site exploration activities. The following sections of this chapter should be appropriately referenced in this rationale. The objectives of the site characterization program should be clearly stated, and the relationship between the information presented in Part A and the planned site characterization program clearly established. In particular, the relationship between the site characterization program and the system component performance requirements specified in Section 6.7 should be described.

List the criteria developed pursuant to Section 112(a) of the Nuclear Waste Policy Act that will be used to determine the suitability of the site for the location of a repository. Include a description of how the information gathered during site characterization will be used to determine if the above criteria are met.

8.2 Issues To Be Resolved and Information Required During Site Characterization

This section should identify all known issues related to siting, design of a geologic repository operations area, and waste package and performance assessment as specified in 10 CFR Part 60. The following sections (8.2.1-8.2.4) should contain discussions of the types of information needed to resolve the issues, including but not limited to the following areas of study:

1. Geomorphology,
2. Stratigraphy,
3. Structural geology,
4. Tectonics,
5. Seismicity,

6. Rock mechanics,
7. Hydrology (surface and ground water),
8. Geochemistry,
9. Climatology,
10. Meteorology,
11. Waste/host-rock interactions, and
12. Coupled thermal/hydrological/mechanical/geochemical interactions.

For each of these areas of study, discuss whether the necessary data will be collected from surface or subsurface portions of the planned site characterization program. If any information need is directly related either to the further development of the conceptual design of a repository appropriate to the site or to modeling efforts, this fact should be clearly stated.

Proposed plans for resolving unresolved issues during site characterization, including the specifications for performing the investigations and the applicability and limitations of the investigations for resolving the issues, should be described.

For each proposed test or other data-collection activity of the full range of site characterization activities, the SCP must describe and support with a complete technical rationale the systematic features of the planned programs that are designed to ensure that:

1. Data are representative of the properties or behavior of the feature, component, system, or process with respect to temporal and spatial scales that are significant to findings required by 10 CFR Part 60;

2. Data are known to a precision and accuracy that are adequate to make the findings required by 10 CFR Part 60; and

3. Data are collected and analyzed under appropriate quality assurance procedures.

8.2.1 Unresolved Issues Related to Design of Geologic Repository Operations

following guidance will be useful in deciding when direct testing of coupled behavior may not be required:

1. The component of the natural system (far-field geology) for which performance credit is taken is characterized adequately for evaluation of overall repository performance.

2. In evaluating overall repository performance, no credit is taken for the near-field host rock that cannot be characterized adequately.

3. Components of the engineered system such as the waste package are designed with adequate conservatism with respect to the coupled thermal conditions that will be encountered. Examples of conservatism in design include limiting the host rock thermal loading and thickening waste container walls.

4. The tests that support the design of the engineered system are carried out under a much wider range of conditions than the anticipated repository conditions. This means that the design of the tests takes into account conditions above and beyond the full range of coupled thermal behavior that is expected to be encountered.

The test plan should specify the scale and the duration of the planned tests and should describe how this scale and duration will be adequate to assess compliance with 10 CFR Part 60.

8.2.2 Unresolved Issues Related to Waste Form and Package

This section should identify the issues related to the waste form and waste package, including the emplacement environment, that were not resolved by preliminary site exploration activities or by research and development conducted prior to the submittal of the SCP. Site-specific plans to resolve these issues during the site characterization program should also be included.

8.2.3 Performance Assessment Issues

8.2.3.1 Substantially Completed Analytical Techniques. Describe those performance assessment techniques, including simplifying assumptions, limitations, and boundary conditions, for which development work is substantially completed, with particular emphasis on identification of the types and quality of data needed and on the plans for documentation, verification, and validation of performance assessments during or after site characterization. In the description, specific sections from other documents such as user manuals and code documentations may be incorporated by reference provided these documents are either publicly available or, if proprietary, are readily available to the NRC.

8.2.3.2 Analytical Techniques Requiring Significant Development. Describe those analytical techniques that are expected to be important for evaluating the performance of the site but that still require significant additional developmental work at the time the SCP is prepared. Include site-specific and generic models and computer codes. Describe the programs formulated for undertaking

the developmental work during site characterization, including plans for documentation, verification, and validation of models and codes.

Describe both the analytical techniques expected to be important for site analysis and the associated data requirements. Available data should be summarized in this section either directly or by reference to other chapters of this plan. For each type of analysis, anticipated simplifying assumptions, limitations, and boundary conditions should be described. The approach to treating uncertainties in performance assessments should be described. Discuss the basis for data extrapolation as a result of planned tests and experiments.

8.2.4 Issues for NRC Review

In this section, any additional issues related to the site or design of the geologic repository operations area that DOE wishes the NRC to review should be presented.

8.3 Planned Tests and Experiments

Planned tests and experiments to be conducted during site characterization should be described in detail. Table 8-1 presents a suggested format for describing the planned tests and experiments. The relationship of the planned tests and experiments to information presented in Part A and to the unresolved issues discussed in Section 8.2 should be clearly stated. In particular, the relationship of the planned tests and experiments to the demonstration of meeting the system component performance requirements should be described. The descriptions of in situ tests should specify the scale and duration of the tests and explain how the planned scale and duration will be sufficient to allow assessment of compliance with 10 CFR Part 60. It is important that the tests be shown to be of sufficient duration to yield meaningful and representative data. The scale and duration of the tests should be related to a determination of the information needed in a license application to determine compliance with the system component performance requirements (e.g., relate scale and nature of testing of coupled thermal effects to the importance of near-field host rock formation to overall repository system performance). The quality assurance program to be applied to data collection during site characterization should also be described.

NOTE: Following issuance of the proposed Revision 1 to Regulatory Guide 4.17 (Task WM 404-4, February 1985), the NRC and DOE held several public meetings on DOE's approach to implementing the proposed guidance. As a result, DOE developed an Annotated Outline for Site Characterization Plans. The NRC provided comments on DOE's Annotated Outline in the meetings and concluded that Revision 4 of DOE's Annotated Outline, dated February 15, 1985, is a reasonable interpretation of and consistent with the regulatory guide. On May 7-8, 1986, DOE and NRC held a public meeting specifically on DOE's proposed implementation of Section 8.3 of the regulatory guide; agreements reached on the detailed guidance in that section are recorded in the meeting minutes. Copies of DOE's Annotated Outline and minutes from the meetings on the Annotated Outline and Section 8.3 of the site characterization are available in the Commission's Public Document Room.

8.3.1 Planned Tests with Radioactive Materials

Identify each planned test that involves the use of radioactive materials. In addition to the information called for in Table 8.1, provide information on the quantity of radioactive material to be used, including its curie content. Explain why this is the minimum quantity of radioactive material necessary for testing. Describe plans for the retrieval of such radioactive material following testing.

8.3.2 Planned Tests That May Affect Capability of Site To Isolate High-Level Radioactive Waste

Describe any planned tests or investigation activities that may affect the capability of the site to isolate high-level radioactive waste. Describe possible ways in which the tests or investigation activities could have such an effect, and provide information on measures to be taken during testing to prevent such occurrences.

8.4 Planned Testing, Instrumentation, and Monitoring

For each test or experiment described above, the testing and instrumentation that will be necessary for the investigation should be described. The description should include testing method and testing apparatus, data collection systems, methods of analysis and reduction of data, and the applicability and limitations of the testing and instrumentation in acquiring the necessary information.

Planned tests or experiments should be designed (1) to reflect state-of-the-art precision and accuracy in the use of instrumentation or equipment and methods of analyses, (2) to employ a scale that will result in representative data, (3) to permit reproducibility and traceability of results, and (4) to statistically determine experimental uncertainties.

For each test or experiment requiring short-term or long-term monitoring, describe the goal of the monitoring and the techniques to be used. The description should include specifications for the monitoring system, the instrumentation and data collection systems, the methods of analysis and reduction of data, and the applicability and limitations of the monitoring system in acquiring the necessary information. Identify and evaluate alternative methods of testing and analysis that might achieve the same goals as the methods proposed.

8.5 Planned Site Preparation Activities

In this section, plans for surface and subsurface excavations related to the site characterization program should be presented.

8.5.1 Surface Site Preparation Activities

Describe the surface activities (e.g., access, clearing, grubbing, stripping) needed to prepare the site for site characterization activities. Include the anticipated start and completion dates. State whether the surface activities are related to site characterization at the surface or whether they are preparatory to subsurface activities. Describe any surface facilities to be erected at the site.

TABLE 8-1*

SUGGESTED FORMAT FOR DESCRIPTION OF PLANNED TESTS AND EXPERIMENTS

1. Title of Test or Experiment

2. Purpose of Test or Experiment

   Summarize why the test or experiment is proposed and what types of information will be obtained.

3. Objectives

   Discuss how the results of the test or experiment will relate to the overall site characterization program. Describe how the results will be used to help resolve specific information needs or unresolved issues.

4. Descriptive Summary

   Summarize the methods, techniques, and analyses used in the test or experiment, and state the precision and accuracy of the test or experiment. Describe in detail the procedures expected to be used. Procedures should describe the experimental design that ensures representativeness of data and demonstrates precision and accuracy.

5. Quality Assurance

   Describe the quality assurance program to be applied to data collection, and discuss the limitations and uncertainty in the data.

6. Principal Investigator

   Give the name and organization of the principal investigator if known.

7. Contact

   Provide the name, address, and telephone number of persons to contact concerning the status of the test or experiment.

*See Note in Section 8.3.

8.5.2 Underground Test Facility

Describe the underground test facility to be used for the in situ at-depth testing portion of the site characterization program. The description should include a detailed technical rationale for the proposed underground testing that addresses the quantity, quality, and scales of data needed to resolve licensing information needs. Based on this rationale, the description should provide a detailed layout of the planned excavation, including design dimensions, boring locations, and the planned location within the test facility of each anticipated test or experiment. In addition, details of construction, including the location of the underground test facility with respect to the conceptual design of a repository appropriate to the site, should be provided. Particular attention should be paid to shafts excavated and borings made for the underground test facility and their location with respect to possible future shafts and excavations. An analysis of the potential impact of in situ at-depth testing on the integrity of the site should also be included.

8.6 Milestones, Analyses, Decision Points

Describe briefly (1) key milestones to be used to mark progress, (2) data analyses to be performed, (3) use of acquired data, including both direct use of the tests and experiments as well as integration of results of tests and experiments to resolve identified issues or to identify new issues, and (4) stages in the site characterization program when options would be assessed and decisions would be made as to how (or whether) to proceed.

8.7 Schedule

Provide a graphic presentation (flow chart) of the site characterization program in which activities, analyses, milestones, decision points, reports, and submittals for NRC, State, Indian tribal, and public review and any other relevant information are identified. The presentation should be constructed so that tasks accomplished and tasks still to be accomplished can readily be identified. The presentation should also include, as appropriate, the logic leading to decision points and selection among alternatives.

8.8 Quality Assurance

Describe the quality assurance (QA) programs that have been applied during site exploration activities and that will be applied during the planned site characterization program, including design activities. References to detailed QA administrative procedures that implement the program should be provided, as well as detailed descriptions of the QA procedures used in specific program technical areas. Although all test plans and procedures will not be completed at the time of submittal of the SCP, those that are completed should be referenced and available for QA review.

The QA methods and technical procedures and plans should be presented in sufficient detail to allow NRC to make an independent evaluation of the precision, accuracy, reproducibility, analytic sensitivity, and limitation of data acquisition and analysis methods that were used during site exploration and that will be used during site characterization.

8.9 Decontamination and Decommissioning

Describe plans for the decontamination and decommissioning of all facilities and structures used in connection with the site characterization program at the candidate site if the site is determined to be unsuitable for application for a construction authorization.

8.9.1 Decontamination

Describe plans for the decontamination of the candidate site. Identify prospective methods to be used in decontamination and the timing of decontamination activities with respect to the cessation of site characterization activities. Describe intended levels of residual radioactivity following decontamination.

8.9.2 Decommissioning

Describe plans for the decommissioning of facilities and structures used in site characterization at the candidate site. Identify surface structures to be removed from the area and those to remain. Provide information on the physical layout of the area following decommissioning.

8.9.3 Plans for Mitigation of Any Significant Adverse Environmental Impacts Caused by Site Characterization Activities

Describe plans for mitigating any significant adverse environmental impacts caused by site characterization activities if such area is determined unsuitable for a construction authorization application for a geologic repository operations area.

APPENDIX A

SEMIANNUAL REPORTS

In accordance with paragraph 60.18(g) of 10 CFR Part 60, DOE must submit semiannual reports to NRC on the progress of site characterization and of waste form and packaging research and development.

These semiannual reports should:

1. Discuss the results of site characterization activities,

2. Identify (a) new issues not previously mentioned in the SCP, (b) plans to resolve these issues, (c) those studies originally planned that are no longer considered necessary and therefore eliminated from the site characterization program, (d) decision points reached during site characterization, and (e) modifications to schedules,

3. Report progress in developing the design of a geologic repository operations area appropriate to the site, and

4. Discuss other topics related to site characterization if NRC requests them.

The NRC does not believe that it is necessary to issue a separate regulatory guide on the format to be used for these semiannual reports. To the extent appropriate, however, this Standard Format provided for the SCP may be used when submitting information in the semiannual progress reports.

VALUE/IMPACT STATEMENT

A draft value/impact statement was published with the proposed Revision 1 to Regulatory Guide 4.17 (Task WM 404-4) when the draft guide was published for public comment in February 1985. No changes were necessary, so a separate value/impact statement for the final guide has not been prepared. A copy of the draft value/impact statement is available for inspection and copying for a fee at the Commission's Public Document Room at 1717 H Street NW., Washington, DC, under Task WM 404-4.

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