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The Yucca Mountain site, located in south-central Nevada, has recently gained a central position in the U.S. geologic repository program. The recent choice of this site as the only potential repository site to be characterized makes it increasingly important that the activities to be conducted during site characterization are both adequate and sufficient to obtain the site data required to determine the licensability of the Yucca Mountain site. The Site Characterization Plan (SCP) was released to the Nuclear Regulatory Commission (NRC), State of Nevada, and the Public in December 1988. Site-specific data requirements are presented in the SCP for the Yucca Mountain site. The approach used to establish the data needed from site characterization relies upon a set of performance and design issues, derived directly from the NRC performance and design requirements in 10 CFR Part 60. Strategies for demonstrating compliance with performance and design issues were developed and are also presented in the SCP. An integral part of the strategy for each issue is a preliminary identification of the site-specific data required for evaluating regulatory compliance. At the current level of maturity of the program, the confidence levels indicating how much information is needed about a given parameter are generally qualitative. With maturation of the program, performance and design-related sensitivity analyses will provide increased definition of the importance of various site parameters so that confidence levels can be made more quantitative.

INTRODUCTION

The Nuclear Waste Policy Act, 1983¹ (NWPA), is the principal law that governs the U.S. Department of Energy's (DOE) repository program. The provisions in that law are many and the details are often quite complex. Through this law, three federal agencies were given key roles in the repository program. These agencies are: the DOE, the U.S. Nuclear Regulatory Commission (NRC), and the Environmental Protection Agency (EPA). Briefly, the DOE was required to create the Office of Civilian Radioactive Waste Management (OCRWM) to manage the disposal of high-level radioactive waste in mined geologic repositories; the NRC was assigned the responsibility to authorize construction of the repository, issue a license to DOE to receive and possess high-level radioactive waste, and, finally, to approve closure and decommissioning of the facility; and the EPA was required to establish limits for radionuclides that could reach the accessible environment in the future.

In December 1987, Congress passed an Amendment² to the NWPA. This amendment act has many features. Among the most significant are: (a) the focus of the site characterization investigations on Yucca Mountain and phase out of the sites at Hanford, Washington, studying basalt host-rock and Hereford, Texas, studying salt host-rock; (b) the authorization of a negotiator to seek negotiations with governors of other states and territories for other potential repository sites that could be characterized; and (c) the establishment of a Nuclear Waste Technical Review Board, appointed by the President, to evaluate the technical scientific validity of activities undertaken by DOE in implementing the NWPA.

In accordance with these laws, there are key regulations with which the DOE will be required to demonstrate compliance. These regulations were the starting point for organizing the SCP and can be summarized as follows: (a) the release of radionuclides 10,000 years in the future must meet the limits in EPA's 40 CFR 191³; (b) the site selection must satisfy DOE's 10 CFR 960⁴; (c) radiological safety for workers and non-workers must meet NRC's 10 CFR 20⁵; (d) licensing of a high-level waste repository must comply with NRC's 10 CFR 60⁶; (e) the quality assurance provisions must satisfy NRC's 10 CFR 50⁷ Appendix B; and (f) the environmental impacts must meet the requirements established in NRC's 10 CFR 51.⁸

The DOE has made important progress in implementing the NWPA since 1982. Five of the eight key documents identified in the act were met by the end of 1988. Documentation released by the DOE supporting these major program activities along with their release dates include the following: Siting Guidelines, 1984⁴; Mission Plan, 1985,⁹ 1987,¹⁰ and 1988¹¹; Project Decision Schedule, 1986¹²; Environmental Assessments, (EA) 1984¹³ (draft) and 1986¹⁴ (final); Site Characterization Plans (SCP), 1988¹⁵ (consultation draft) and 1988¹⁶ (statutory version). The four major documents specified in the NWPA are the: EA, SCP, Environmental Impact Statement (EIS), and License Application (LA). These documents form the basis for the most impor-

tant DOE program decisions. The EA's were the basis for the DOE to screen from nine to three sites for intensive site characterization that may last five to seven years. Each of the three sites remaining after the screening possessed the technical attributes called for in 10 CFR 960,⁴ on the basis of the available information. It is anticipated that technical criteria specified in 10 CFR 960⁴ will become the basis for DOE to assess the suitability of Yucca Mountain during the time the EIS (draft 1993, final 1994) is prepared. Work on the EIS is expected to begin in the next few years with the initiation of scoping hearings.

The consultation draft of the SCP¹⁵ was issued in early January 1988. Numerous technical meetings were held with the NRC and State of Nevada during 1988 about DOE's approach to site characterization. In late January, a meeting was held in Reno, Nevada, where the DOE explained the contents of the draft SCP, on a chapter by chapter basis, to the staff from the State of Nevada's Nuclear Waste Project Office, the NRC and the public. In early April 1988, the DOE met for a week with the technical staff of the NRC and State to receive their comments and suggestions about the SCP.¹⁵ In May 1988, the DOE received written comments about the SCP¹⁵ from both the NRC and U.S. Geological Survey (USGS). Later in April 1988, the DOE held a week long meeting with the NRC, State, and public to exchange ideas about alternate conceptual models of the hydrologic system applicable to Yucca Mountain, Nevada. In June 1988, the DOE briefed the NRC's Advisory Committee on Nuclear Waste. In July and October 1988, the DOE met with the NRC and State in week long meetings about the Exploratory Shaft Facility (ESF) design and design control. In November and early December 1988, the DOE met with the NRC and State to discuss the regulations that apply to the ESF and the analyses needed to support Title I design of the ESF. In mid-December, DOE briefed the NRC's Atomic Safety and Licensing Board Panel and hosted a visit to the site for the board members. In late December the DOE met with the NRC and State to discuss DOE's content of the Study Plans, now in preparation, that describe in much greater detail the 107 studies described in the SCP. These meetings have helped the DOE improve the content of the SCP as revisions were made to the consultation draft SCP¹⁵ in the preparation of the statutory SCP.¹⁶ After the release of the statutory SCP,¹⁶ in late December 1988, the NRC will conduct an intensive technical review and issue a Site Characterization Analysis in a three to six months timeframe.

With the issuance of the statutory SCP,¹⁶ even more extensive technical interactions between the DOE and the NRC will occur. Although there will be SCP progress reports issued every six months during site characterization, it is anticipated that some of the most meaningful technical interactions will occur via workshops and meetings where technical position papers, provided by the DOE, explain the basis for why a topic (e.g., seismic design requirements for the surface facilities) has been adequately investigated. The concept of position papers is discussed later in more detail.

Two other major activities in the program that feed these DOE/NRC interactions

are: design and performance assessment. Design activities for the repository and waste package that required site information are presented in the SCP.¹⁶ Additional detail is given in a repository Conceptual Design Report.¹⁷ This conceptual design for the repository will evolve to an advanced conceptual design and eventually a license application design. During the maturation of the conceptual design, site investigations will be providing geology, hydrology, geochemistry, etc. that serve to refine both the design and performance assessment of the system.

Site investigations in the vicinity of Yucca Mountain have occurred for many years due to its proximity to the Nevada Test Site. Although information from these site investigations has been adequate to support a preliminary conceptual design, this information is insufficient to proceed to advanced designs. Therefore, intensive site characterization is planned, as described in Chapter 8 of the SCP,¹⁶ to acquire enough information to support a design for license application to the NRC. This intensive characterization has two major activities: (a) broadly scoped surface-based field studies aimed at understanding the processes acting on the structural framework of Yucca Mountain and (b) underground in situ studies conducted in the exploratory shaft facility at the potential repository horizon in the Topopah Spring member of the Paintbrush Tuff. During the next 5-7 years, the DOE will be trying to analyze the potential of the system (i.e., site and repository) to effectively contain and isolate radioactive waste for the 10,000-year period specified in 40 CFR 191.³ Multidiscipline position papers incorporating information from site investigations and design will be prepared for assessing the long-term performance of the system and will provide the information needed for important DOE/NRC interactions.

SITE CHARACTERIZATION PLAN

The goal of site characterization as described in Chapter 8 of the SCP¹⁶ is to acquire data to support analysis and calculations that will allow evaluation of the ability of Yucca Mountain (including the repository) to satisfy the performance objectives of 10 CFR 60.111-.113 identified in Figure 1. Demonstrating that these objectives can be met will be a real challenge. The analyses and calculations will be complex and there will undoubtedly be considerable debate by scientists and engineers, alike, between the DOE and NRC for many years. It is indeed unfortunate that there is no single site measurement that can be made that will simply, and unambiguously, demonstrate compliance with these numerical performance objectives.

However, there is a definite relationship between performance, design, and the site that has helped to organize the process for demonstrating compliance. Simply speaking, the performance objectives dictate data required from both design and site characterization. Also, the design dictates data required from site characterization. Therefore, a primary goal for the site characterization program is to provide data that will be

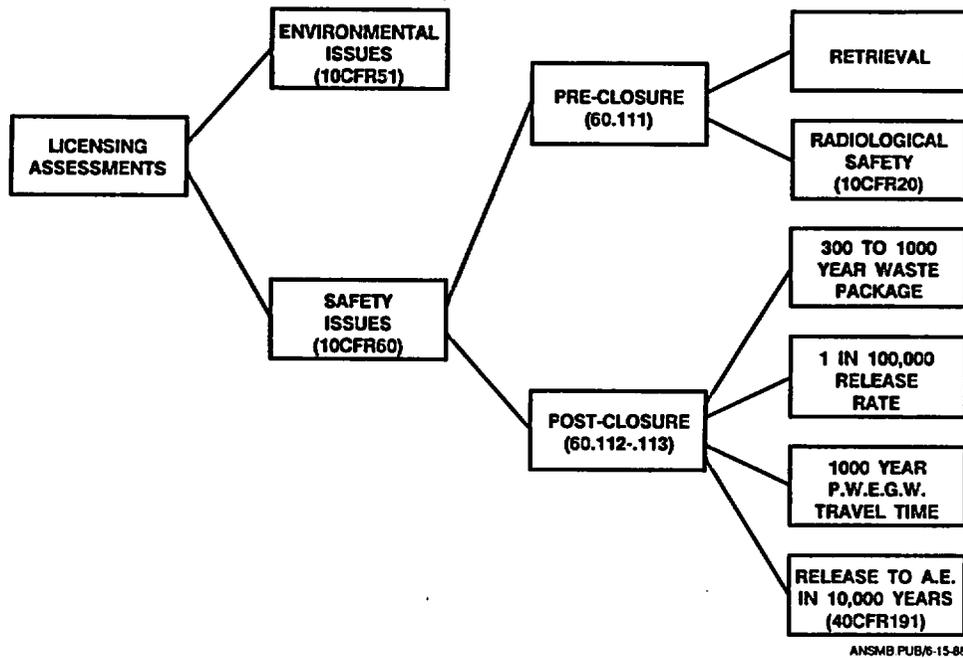


FIGURE 1. Organization of performance objectives from 10 CFR 60 which became the principal focus for Chapter 8 in the site characterization plan.

used by both design and performance assessment functions. This relationship is reflected in the Issues Hierarchy¹⁸ which became an organizing tool for Chapter 8 of the SCP, linking the regulations with the characterization program through the performance and design issues as shown in Figure 2. The principal regulatory requirements in 10 CFR 60,⁶ 40 CFR 191³ and 10 CFR 960⁴ were translated into 23 performance and design issues that request a myriad of information which must be acquired by some 16 broad site characterization program investigations.

Although the basic content of the site characterization plan is established in the NWPA, additional details are specified by the NRC in Regulatory Guide 4.17¹⁹ and a DOE Annotated Outline.²⁰ The statutory SCP¹⁶ consists of 9 volumes which includes 8 chapters and an index, as shown in Table I. This comprehensive document is approximately 6,000 pages long and took over 300 scientists and engineers approximately four years to write. Chapters 1-5 describe what we know from the available information about the site geology, geoengineering, hydrology, geochemistry, climate and meteorology, while Chapters 6 and 7 describe preliminary conceptual designs for the repository and waste package. While writing these seven chapters and trying to explain what

THE ISSUES HIERARCHY

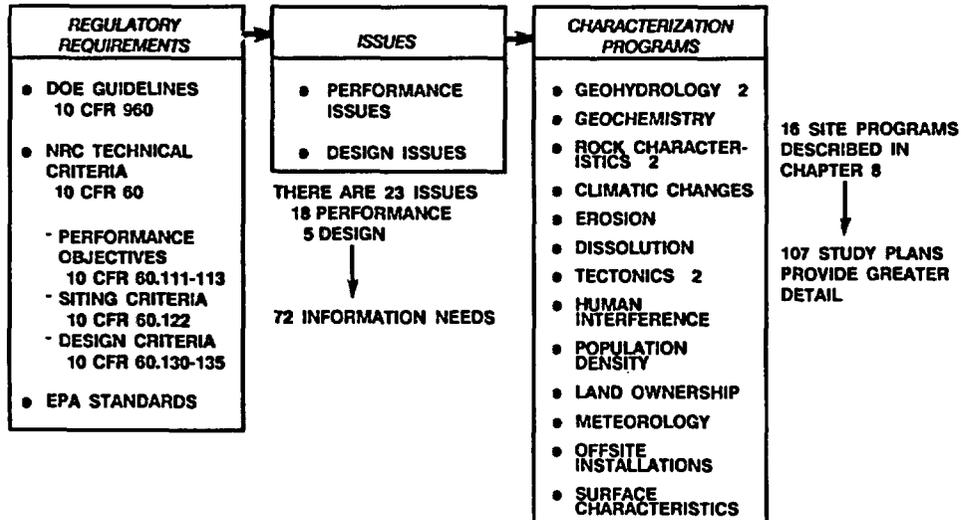


FIGURE 2. The Issues Hierarchy—an organizing tool for Chapter 8 in the site characterization plan that links the regulations with the characterization programs through the issues.

we know from the available information, we also improved our understanding of what we did not know about the processes and events that are acting upon the site to change it over the next 10,000 years. These chapters (i.e., Chapters 1 through 7) very briefly review what remains to be understood, and therefore, establish a linkage to Chapter 8. For those persons interested, an Overview²¹ of the SCP¹⁶ has also been prepared.

Examining the content of Chapter 8 in a little more detail shows that the 23 performance and design issues have created 72 information needs and these are described in greater detail in 121 activities in Sections 8.3.2 through 8.3.5 in Chapter 8. For performance assessment, there are 18 issues, 54 information needs and 101 activities described in Section 8.3.5. of Chapter 8. These 101 activities have been divided into three topical areas, as shown in Figure 3: engineered barrier system—26, repository performance—53, and operational safety—22. As evidenced by the number of tasks, repository performance encompasses largest effort. For design, there are five issues, 18 information needs, and 20 activities described in Sections 8.3.2, 8.3.3 and 8.3.4 of Chapter 8. These 20 activities have been divided into three topical areas, which are

TABLE I
Content of Site Characterization Plan¹⁶ as
Determined by NRC's Regulatory Guide 4.17
and DOE's Annotated Outline OGR/B-5

Chapter 1	Geology
Chapter 2	Geoengineering
Chapter 3	Hydrology
Chapter 4	Geochemistry
Chapter 5	Climatology and Meteorology
Chapter 6	Conceptual Design of a Repository
Chapter 7	Waste Package
Chapter 8	Site Characterization Program
	Rationale
	Issues and Information Needs
	Planned Tests, Studies, Analyses
	Milestones
	Quality Assurance
	Decontamination and Decommissioning
Index	
	(9 volumes)

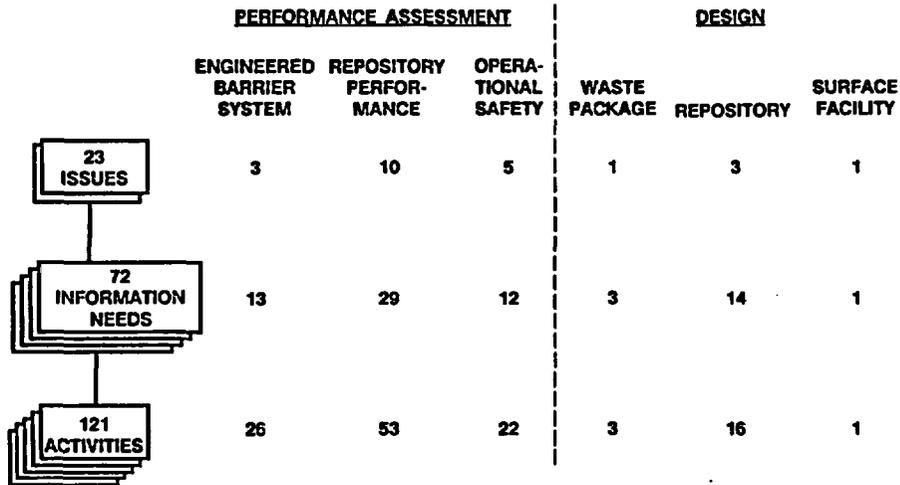


FIGURE 3. The performance and design programs described in Chapter 8 of the site characterization plan.

also shown in Figure 3: waste package, repository, and surface facility. As evidenced by the number of tasks, repository design encompasses the largest effort.

In order to respond to requests from the performance and design issues, the site program has created 42 investigations in six broad topical areas, as shown in Figure 4. These 42 investigations have been further subdivided into 107 studies which are, in turn, subdivided into 308 activities described in Section 8.3.1 of Chapter 8. The general goal of the investigations is to improve our understanding of the existing site characteristics and the processes acting that could change these characteristics during the next 10,000 years, especially those processes that could be disruptive to containment and isolation (e.g., tectonics) of radionuclides. The general objectives for the 308 activities in these six topical areas are as follows:

hydrology—57 activities to better understand water flow paths and ground-water travel time in the unsaturated and saturated zones.

geology—41 activities to improve our knowledge of the three-dimensional framework of Yucca Mountain.

tectonics—102 activities to assess the risks from seismicity, faulting, and volcanism to surface and underground facilities and to assess what impact tectonic events could have on hydrology.

climate and meteorology—27 activities to study the past climate at Yucca Mountain and to predict the future climate so that future climatic influences on hydrology can be assessed.

	HYDROLOGY	GEOLOGY	TECTONICS	CLIMATE METEOROLOGY	GEOCHEMISTRY NEAR/FAR FIELD	ROCK PROPERTIES SEALS
42 INVESTIGATIONS	8	10	8	6	9	3
107 STUDIES	20	17	30	9	20	11
308 ACTIVITIES	57	41	102	27	53	28

FIGURE 4. The site program described in Chapter 8 of the site characterization plan.

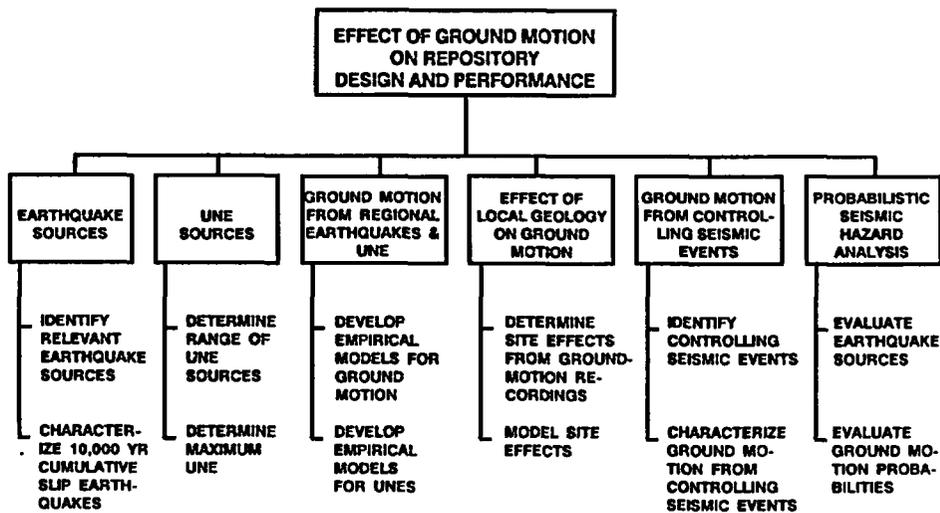


FIGURE 5. Numerous activities that support 6 studies needed to satisfy the objectives of a site investigation about the effects of groundmotion on repository design and performance.

geochemistry—53 activities to improve our understanding of the distribution and amount of sorptive minerals along potential flowpaths of radionuclides and to assess the ability of the site to retard radionuclides when they escape from the waste package.

rock properties—28 activities to improve our knowledge of the physical characteristics to assess the response of the rock to the repository conditions.

The relationship between the site investigations, studies, and activities are illustrated in Figure 5 which is an example of numerous activities that support six studies which will be needed to assess the effect of ground motions on the design and performance of a repository.

POSITION PAPERS

Multidisciplinary position papers are expected to combine the results of several studies to help lay the foundation, or building of blocks, for preparing the LA. These position papers will provide a focus for the DOE and NRC to interact about controversial topics that will eventually require an explicit demonstration of compliance with 10 CFR 60. As shown in Table II, current thoughts suggest that a position paper about the seismic design requirements for surface facilities would call for 11 technical elements

TABLE II
Technical Elements Needed to Support Preparation of a Position Paper
about Seismic Design Requirements for Surface Facilities

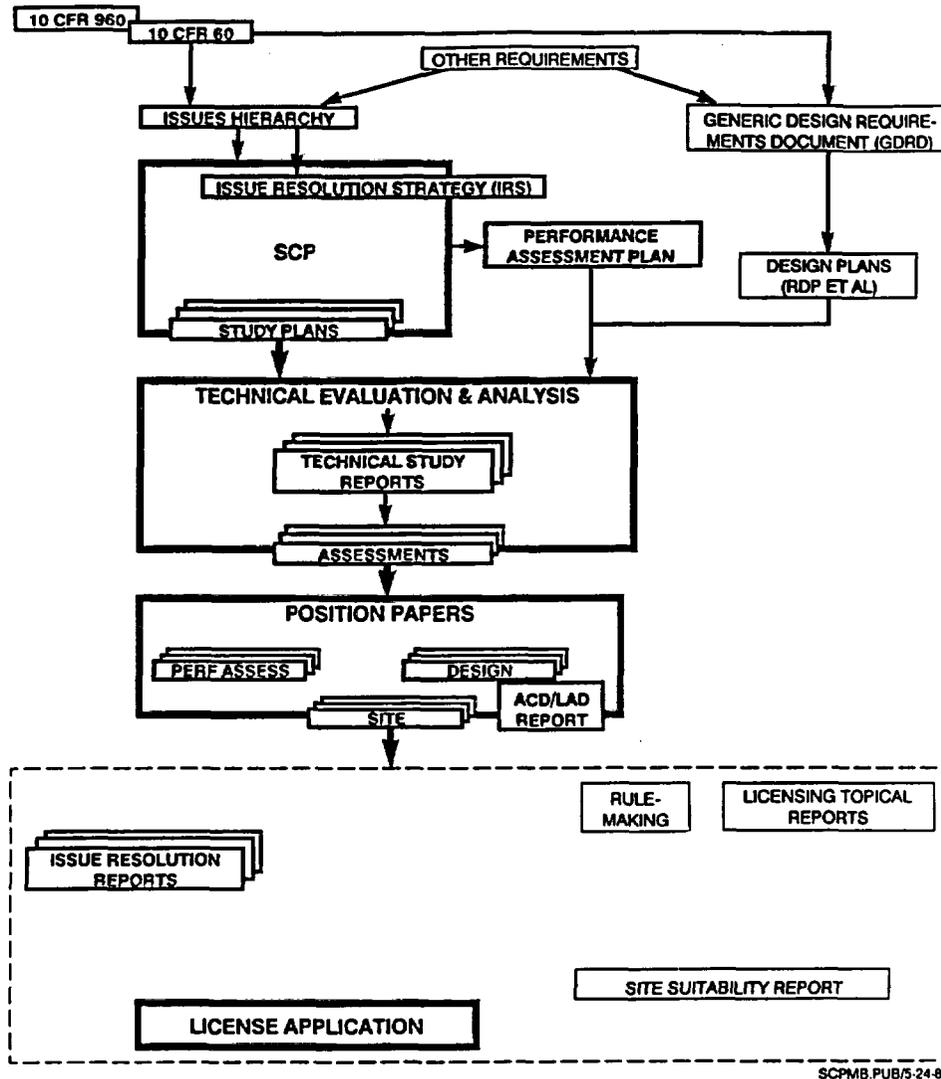
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- I. Seismic Design of Surface Facility
 - A. Probabilistic seismic hazards analyses—probabilities of exceeding different ground levels
 - B. Ground motion at the site from the controlling seismic events (time histories and response spectra)
 - 1. Selections of ground motion models
 - a. Maximum potential underground nuclear explosions
 - b. Selection of earthquakes for consideration in seismic design
 - (1) Identification and analyses of earthquake sources which could impact design
 - (a) Seismicity of region
 - (2) Quaternary faulting within site area—recency of movement for all significant Quaternary faults
 - (a) Quaternary faulting within 100 km
 - 2. Effects of local site geology on surface motions
 - a. Analysis of behavior of surface rock and soil
-

of data or analyses before the design requirements can be clearly elucidated on this topic.

DOCUMENTATION TO SUPPORT LICENSE APPLICATION

In summary, the documentation required to plan site characterization and to demonstrate compliance is anticipated to be quite extensive. The process shown in Figure 6 illustrates, conceptually, three phases, (i.e., SCP, Technical Evaluation and Analysis, and Position Papers). These phases are consistent with: (1) data acquisition during site characterization, (2) evaluation and analyses of that data, and (3) application of that data and analyses to develop technical positions to facilitate interactions between DOE and NRC with a goal to provide building blocks, or modules, that can support demonstration of compliance with 10 CFR 60 in the LA.

The goal of the repository is to protect the safety and health of the public for a period of 10,000 years. A data base and confidence levels must be developed in a manner consistent with this goal. There are no standard criteria that can be used to determine the confidence level required for a given type of data to ensure public health and safety. However, a conservative approach has been taken in the SCP by specifying the same type of data be acquired using multiple sources and/or by different test methods. The process for refining confidence levels must be interactive, in that performance



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FIGURE 6. Three subphases of site characterization that the geotechnical program will pass through as it matures: (1) site characterization plan—concentrates on data acquisition, (2) technical evaluation and analyses—concentrates on interpretation of data, (3) position papers—concentrates on syntheses and demonstrating how topics meet the requirements in 10 CFR 60.

and design analyses can initially be used as a screening tool to eliminate site parameters from consideration if they can be shown to have little or no potential impact on repository performance. The data required to predict the range of variation in site conditions that is likely over the next 10,000 years, and the information necessary to estimate the probabilities of catastrophic natural events must be obtained to support these iterative analyses. Sensitivity studies utilizing the most recent data can be conducted in support of determining confidence levels for the most important key geotechnical processes and disruptive events that can impact containment and isolation.

SUMMARY

The Yucca Mountain site, located in south-central Nevada, has recently gained a central position in the U.S. geologic repository program. The recent choice of this site as the only potential repository site to be characterized makes it increasingly important that the activities to be conducted during site characterization are both adequate and sufficient to obtain the site data required to determine the licensability of the Yucca Mountain site. In December 1988, the DOE released to the NRC, State and public the Statutory Site Characterization Plan.

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