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FROM: Robert J. Wright
BWIP Project Manager, WMHT

SUBJECT: DRAFT 1 OF DRAFT SITE CHARACTERIZATION ANALYSIS

Attached is Draft 1 of the DSCA, consisting of Chapters 1 though 11. As shown in the review schedule, the Executive Summary, Director's Opinion and Chapter 12 will be incorporated into Draft 3, and the Appendices will be included in Draft 4.

Please review the attachment and provide comments, handwritten on the draft, to the appropriate authors by COB Wednesday, December 15. To maximize the usefulness of your input: 1) specify the changes that, you believe, represent improvements in the text and; 2) recommend specific wording, where possible.

Draft 2, incorporating the comments of reviewers, is due by COB, Monday, December 20. It should be delivered by each author to the SCR in-box in the WMHT office. If you have difficulty in resolving comments, please consult me.

OFC :						
NAME :						
DATE :82/12/10						

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If you need additional copies of Draft 1 for review purposes, please see me.

Robert J. Wright
BWIP Project Manager
High-Level Waste Technical
Development Branch
Division of Waste Management

Enclosure:
DSCA (Draft 1)

PRE-DECISIONAL IN NATURE

OFC	WMHT	WMHT					
NAME	RWRIGHT:ls	HJMiller					
DATE	82/12/10	12/10/82					

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End to 12-9-82 memo fm RWright

1 DESCRIPTION OF LICENSING AND SITE CHARACTERIZATION REVIEW PROCESS

1. Submission of BWIP Site Characterization Report

The U.S. Department of Energy has filed with the Nuclear Regulatory Commission the "Site Characterization Report for the Basalt Waste Isolation Project," DOE/RL 82-3(BWIP SCR). The BWIP SCR is for a candidate high-level waste repository on the Hanford Reservation in the State of Washington; it was received by the Commission on November 12, 1982, and has been designated as Project WM-10.

The submission of the SCR is pursuant to the Commission's procedural rule regarding disposal of high-level radioactive wastes in geologic repositories. The rule is codified at 10 CFR Part 60 and was published February 25, 1981 (46 FR 13971). In accordance with K60.11, "As early as possible after commencement of planning for a particular geologic repository operations area, and prior to site characterization, the DOE shall submit . . . a Site Characterization Report."

The BWIP SCR is presented in three volumes and contains 19 chapters and approximately 2200 pages. The complete table of contents of the BWIP SCR is included as Appendix B of this Draft SCA.

It should also be noted that under 10 CFR Part 51, K51.40(d), DOE is required to characterize at least three sites representing two geologic media, one of which is not salt, as "the minimum necessary to satisfy the requirements of NEPA [the National Environmental Policy Act]." DOE has informed NRC that it has ongoing studies at Yucca Mountain at the Nevada Test Site (NTS), as well as salt sites in the Gibson Dome area of Utah's Paradox Basin, the Texas Panhandle area of the Permian Basin, and four salt domes in the Gulf Interior Region in Louisiana, Mississippi, and Texas. A description of DOE activities in these areas is presented in Chapter 19 of the BWIP SCR. DOE has not notiified NRC of any final decision as to which of the sites it will characterize.

A copy of the BWIP SCR is available for public inspection at the Nuclear Regulatory Commission, Public Document Room, 1717 H Street, Washington, DC 20555. Copies of the SCR are available from the U.S. Department of Energy, Richland Operations Office, ATTN: Mr. Lee Olson, P.O. Box 550, Richland, WA 99352, Telephone (509) 376-7334 or FTS 444-7334.

1.2 Purpose of the Site Characterization Report

The basic purpose of the SCR is clear: to provide a mechanism for identifying problems at a proposed repository site and the plans for resolving them at an early time in order to avoid delays in the licensing process.

The specific requirements for contents of the SCR are contained in K60.11(a). Further guidance on preparing an SCR is contained in NRC Regulatory Guide 4.17, "Standard Format and Content of Site Characterization Reports for High-Level Waste Geologic Repositories." Copies of Reg. Guide 4.17 are available from NRC/GPO Sales Program, Division of Technical Information and Document Control, Nuclear Regulatory Commission, Washington, DC 20555.

The SCR, in accordance with the Standard Format and Content, should accomplish the following:

1. Establish what is known about a site from site screening, selection and 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 of work for data acquisition and analysis to meet information needs for issues.

1.3 Purpose and Method of Site Characterization Analysis

In accordance with K60.11(d), the Director of NRC's Office of Nuclear Material Safety and Safeguards (Director) has prepared this Draft Site Characterization Analysis (Draft SCA) of the information provided in the BWIP SCR. This Draft

SCA is advisory in nature; it conveys NRC comments and advice on the thrust of DOE's plans for site characterization.

A period not less than 90 days will be allowed for public comments on the Draft SCA. The Director will then prepare a final site characterization analysis issuing an opinion that the Director has either no objection to DOE's site characterization program, if such an opinion is appropriate, or specific objections to DOE's proceeding with characterization of the named site. In addition, the Director may make specific recommendations to DOE on matters relating to its site characterization activities.

This Draft SCA is a critique of the plans of the DOE contained in the SCR, enphasizing open items for continued follow-up discussion. Readers of the SCA interested in detailed aspects of the DOE site characterization program will have to consult the BWIP SCR.

The NRC staff review of this SCR is not a licensing proceeding, but part of an ongoing pre-application process. This process is designed to enable DOE to gather the information it needs to decide whether to apply for a license--or more specifically, an NRC authorization to construct a repository at a particular site. The SCR review process is intended to be a vehicle for identifying at an early stage what the specific potential licensing issues are at a site based on what is known from investigations to date. It permits an opportunity for consultation between the DOE and NRC, with public involvement, on the site characterization and data gathering programs that the DOE plans in order to be able to address and resolve identified issues. To ensure continuous review of DOE activities at each site, DOE is required by NRC regulations to submit semiannual reports on the progress of site characterization.

1.4 SCR Review Procedure

In preparation for the BWIP SCR review, a BWIP review team was named and a project manager was selected prior to SCR receipt. All of the individuals on the review team are NRC staff; most are members of NRC's High-Level Waste Technical Development Branch (WMHT) and the High-Level Waste Licensing Management Branch (WMHL) in the Division of Waste Management, Office of

Nuclear Material Safety and Safeguards. These individuals had primary responsibility for developing this Draft SCA. In addition, assistance was provided by NRC personnel from other offices, namely: the Office of Research, the Office of the Executive Legal Director, and the Office of State Programs.

Prior to SCR receipt, the BWIP review team undertook a variety of activities to prepare for the SCR review. These activities included conducting several on-site technical reviews of DOE activities at BWIP; participating with BWIP personnel in technical workshops to identify issues and exchange technical information; developing technical background material; reviewing available site data; and establishing and maintaining contact with DOE technical staff, State agencies and other individuals and organizations who are likely to be involved in the preparation and review of the Draft SCA. Some of these activities, such as site visits, began as early as 1981. NRC staff plans to continue these activities, as necessary, throughout the DOE site characterization program.

More specifically, based on available information and prior to SCR receipt, the BWIP Review Team prepared an inventory of documents and other data pertaining to BWIP and developed a systematic and comprehensive review of BWIP site issues. Next the review team prepared a partial, preliminary Site Issue Analysis (SIA - see 1.5 below for a description of these) for each site issue and annotated outlines of portions of the Draft SCA text and appendices.

Upon receipt of the BWIP SCR, NRC's BWIP review team, based upon a thorough review of the SCR, finalized the Site Issue Analyses and prepared the Draft SCA text and appendices.

1.5 Site Characterization Analysis Products

The NRC analysis of the BWIP SCR includes the development of the following separate and distinct products:

Draft Site Characterization Analysis (Draft SCA)

The Draft SCA is a critique of the SCR, focusing on major concerns and comments on the basic thrust and strategy of the DOE program, especially those plans now on the critical path for licensing. The Draft SCA is used to check the completeness and adequacy of the issues presented by DOE in the SCR and is the basis for developing the basic units - Site Issue Analyses - in the NRC review. The Draft SCA is published as a NUREG. It contains various summary tables and is supported by numerous appendices and site issue analyses as described below. The Draft SCA is not a complete summary or restatement of the SCR; the reader must refer to the SCR for details.

Chapters 3 through 11 of the Draft SCA contain critiques of key issues in site selection, groundwater flow, geologic stability, geochemical retardation, design of facilities, waste package, institutional and environmental factors, quality assurance and performance assessment respectively. In addition to these key issues, all other NRC concerns that will require further interactions with DOE are summarized in Chapter 12. The full development of all these issues is presented in Appendix C.

SCA Appendices

Appendices were prepared by NRC staff to support selected aspects of analyses in the Draft SCA text. The appendices are a part of the Draft SCA and are contained in the NUREG document. The major appendices are:

Appendix A. Maps and Sections of the Hanford Reservation - Maps of the site.

Appendix B. Table of Contents of the SCR - Complete reproduction of the table of contents of the BWIP SCR.

Appendix C. Tabulation of Site Characterization Issues - A comprehensive and systematic identification of all concerns and open issues at the site. This includes a comparison and cross reference between NRC and DOE issues.

Appendix D. Sensitivity Analyses - Preliminary studies of elements in performance assessment of the site, incorporating selected hydrogeologic parameters and simplifying assumptions. This includes an evaluation of performance assessment at a broad level of detail using simple models commensurate with current levels of uncertainty in the controlling parameters. These analyses were performed to (1) determine what are the important issues in terms of system performance and (2) integrate the activities of various reviewers examining individual elements of system performance, since the importance of any single element cannot be determined in isolation. The analyses incorporated into the Draft SCA are precursors to more detailed and complete performance assessments NRC will do in licensing reviews. The focus at this stage in the DOE program (i.e., prior to beginning detailed site characterization activities) is on the uncertainties in the parameters. The rackout of issues described in Appendix C was developed by rigorously considering the performance assessments that will have to be done in licensing.

Appendices E thru BB. Detailed Technical Analyses - Detailed, site-specific data and analyses which provide supporting information for selected, major site issues as addressed in Chapters 3 through 12 in the Draft SCA text. Typical information includes hydrostratigraphy and geologic controls, environmental conditions for the waste form and metallic waste package component, stability of openings, retrievability systems and other subjects as appropriate to the BWIP site.

Site Issue Analyses (SIAs)

An analysis of all major site-specific issues - at least in some level of detail - were prepared by NRC staff. Each analysis includes technical backup attachments developed by NRC staff and NRC contractors as necessary. The SIAs accompany the Draft SCA in the Public Document Room but are not formally included in the Draft SCA NUREG document. Each SIA includes: a summary of the issue and an evaluation of DOE plans for investigations and tests to acquire information to resolve the issue.

References

Selected, key technical reports of NRC contractors are included as references to the Draft SCA. This includes the general results of major technical assistance efforts of a several year period addressing selected, major issues and identifying the basic elements of an acceptable site characterization program to allow addressing these issues in licensing. These reports focus on chief technical issues, such as those in geochemistry and hydrology, which are new, unconventional and unique to a high-level waste repository.

2 DESCRIPTION OF FACILITY AND CONCEPTUAL DESIGN

2.1 General Discussion

As required in the Procedural Rule (10 CFR 60), DOE has provided a description of the Conceptual Design for BWIP. This is provided in Chapter 10 of the SCR.

2.2 General Description of the Surface Facilities

The surface facilities are based on a conceptual design which will provide the basic functions of waste receipt, overpacking, and transfer to the repository waste transport shaft; handling and disposal of excavated rock; and ancillary services. The surface facilities are arranged around the repository shafts in an attempt to minimize area requirements, travel and transportation distances, and includes the following principal components:

- Facilities for administration, engineering and personnel, including a visitors center
- Equipment and storage area for excavated rock and supplies
- Transportation, maintenance, service, training center, and communication facilities
- Safety and security installations
- Waste handling facilities.

The restricted area (fenced) of the surface facilities forms an irregular polygon that covers approximately 220 acres (89 hectares) (Reference Figure _____). A control zone will extend 6,562 ft (2 km) beyond the outer limits of the subsurface repository. The area within the control zone, but outside the underground repository limits, emcompasses 9,473 acres (3,834 hectares) (Reference Figure ______).

2.2.1 Surface Facilities Important to Safety

Buildings important to safety will be constructed to QA Level I standards as established in 10CFR50, Appendix B. These facilities will consist of:

- Waste Handling Building;
- Personnel and Material Access Facility, Headframe Portion;
- Standby Generator Building;
- Security Headquarters;
- Mine Exhaust Air Building;
- Confinement Exhaust Ventilation Building;
- Basalt Headframe
- Confinement Air Intake Building

These buildings will all be sealed, monolithic, concrete structures. The remainder of the buildings will be of conventional construction, not of confinement type construction.

2.2.2 Waste Handling Facility and Systems Important to Safety

The waste handling building receives and processes both remote-handled and contact-handled waste, and transfers them to the headframe area of the waste transport shaft for lowering to the subsurface facilities. This multistory, monolithic, concrete structure provides confinement for the waste handling process, i.e., separates potential sources of contamination from the public and from the operating personnel.

The core of the building is the second-story hot cell flanked by the operating gallery and the service gallery. On the ground floor beneath this group, the shipping cask unloading area provides a space in which the cask is upended and connected to the shielding sleeve from the hot cell, thus providing a confined route for transfer of canisters from the cask to the hot cell. Above the hot cells is the transfer cask in which canisters are loaded into the transfer cask for transfer to the waste cage in the headframe area.

A contact-waste handling area is located in the west side of the building. Waste containers are unloaded in a receiving area and are transferred by air pallet to the drum unloading area. There drums are removed from the containers, inspected, decontaminated, palletized, and moved through the low-level waste transfer room to the headframe are by forklift, for loading into the mine cage.

The building support areas include radwaste treatment, ventilation fan and filter rooms, mechanical and electrical rooms, service areas, and adminstrative areas.

Two separate ventilating systems are furnished in the building: the confinement system for the waste-handling area and a standard ventilating system for support and administrative areas. The confinement system supplies fresh air to the waste-handling areas and exhausts it through HEPA filters to the stack.

2.3 Subsurface Facilities and Conceptual Design Details

The subsurface facilities include the shaft pillar, main entries, storage panels (for 10 year old spent fuel and commercial waste), experimental panel, and contact waste-storage panel. These are engineered excavations in the repository horizon at a depth of approximately 1100 meter (3700 ft) and are developed from the shaft stations, providing storage capacity for projected nuclear waste receipts. The repository layout (Reference Figure ____) is at the conceptual stage of design development. This design includes a proposed design that has optimized the repository layout. The proposed schedule for design development is outlined in a series of network diagrams (Reference Figure ________).

Shaft pillar facilities include areas for waste transfer, bulk material handling, maintenance, stores, service equipment and personnel, and administrative functions. Two independent ventilation systems are provided: a confinement air circuit to serve areas of the facility where nuclear waste is handled or stored, and a mining air circuit to serve development and support activities. A waste-shaft station unloading area and a transporter loading area are provided to handle the waste packages. They are laid out for efficient waste-cage unloading and transporter loading.

The waste storage panels develop space for one year receipts. The storage and design is based on emplacement of canisters in horizontal holes (Reference Figure ____). Main access ways leading to panel areas are separated from storage panels by a zone of pillar rock. The conceptual design has considered the analysis of data developed from preliminary tests of rock stress and strength (Reference Figure ____).

The layout and spacing of the main access ways allow the total separation of the two air circuits. The main access ways will remain operational throughout the retrieval period.

The staff notes that preliminary plans for backfill (engineered barriers) and seals in the repository are outlined in Sections 10.7 and 10.8 of the SCR. The conceptual design for backfill is a mix of bentonite pellets and crushed basalt. The seals are being designed and are treated as a component of a multiple barrier system.

3 SITE CHARACTERIZATION ANALYSIS: THE SITE SELECTION PROCESS

3.1 Introduction

In this chapter of the Site Characterization Analysis, the staff will analyze the process by which DOE selected a reference repository location at the Hanford Reservation. Beginning in section 3.3, the staff will briefly describe specific aspects of the site-selection process. These descriptions either restate or paraphrase the Site Characterization Report and its references. The staff's analysis will follow each description.

3.2 The National Waste Terminal Storage Program

The DOE has given the National Waste Terminal Storage (NWTS) Program the task of finding and characterizing sites for a geologic repository. The NWTS geologic field offices are investigating basalt (the Basalt Waste Isolation Project (BWIP)), volcanic tuff (Nevada Nuclear Waste Storage Investigations (NNWSI)) and salt and crystalline rocks (Office of Nuclear Waste Isolation (ONWI)) as potential geologic media for a high level waste (HLW) repository. Figure ____ in Appendix A shows where these investigations are taking place.

Basalt, volcanic tuff, and salt are the primary media under consideration. A schedule for the activities planned for each of these media appears in Figure___, Appendix A. The BWIP site characterization report (SCR) is the first of three SCR's DOE will submit to NRC. The SCR for tuff is scheduled for June 1983, and for salt, July 1983.

The NWTS Program is following a three phase siting process consisting of (1) site screening (2) detailed site studies, and (3) site selection (see Figure___ in Appendix A). This siting process is described in the DOE Public Draft, National Plan for Siting High-Level Radiactive Waste Repositories and Environmental Assessment, DOE/NWTS-4 (Ref. 7). (The staff will refer to this document as the National Siting Plan). A brief description of each phase of the siting process follows.

3.2.1 Site Screening

The first phase of the siting process, termed site screening, covers the activities planned to find sites favorable for waste isolation. DOE uses several approaches to begin site screening. The approaches differ in their geographic starting points. The host-rock approach begins by identifying large, multi-state regions of the country, overlying geologic formations of potential interest. Early in the NWTS program, DOE used the host rock approach to delineated regions containing salt domes and bedded salt formations which may be suitable for a geologic repository. More recently, DOE has screened the U.S. for regions containing crystalline rocks such as granite.

Another approach, termed the land-use approach, investigates land already owned by the federal government and committed to nuclear activities. In particular, DOE has initiated siting studies in Nevada (Nevada Test Site) and Washington (Hanford Site) using the land-use approach. Although DOE is pursuing two additional approaches to site screening (province screening and simultaneous screening), DOE expects that the nation's first repository will be selected by either the land-use or host-rock approach.

3.2.2 Detailed Site Studies

After completing site screening, DOE will begin detailed site studies. Here, DOE assesses the safety, environmental, regulatory, and societal concerns associated with constructing and operating a geologic repository at a particular site. The BWIP Site Characterization Report (SCR) details how DOE plans to make the above assessments at Hanford.

3.2.3 Site Selection

Site selection is the process by which one or more sites are selected by DOE with the intent to apply for a construction authorization from the NRC.

(licensing process). As part of the licensing process, DOE will prepare a Safety Analysis Report and an Environmental Report for the repository site it has chosen. The NRC, in turn, will prepare an Environmental Impact Statement for its decision to authorize the construction of the repository.

3.3 Selection of the Hanford Reservation

3.3.1 DOE Rational For Its Selection of the Hanford Reservation

The DOE is considering the thick basalt sequence of the Columbia Plateau for siting a repository for radioactive wastes. The Columbia Plateau covers 78,000 mi^2, extending across southeast Washington and parts of Idaho and Oregon. In 1976, DOE began site feasibility studies in the Columbia Plateau to assess the hydrologic and geologic properties of basalt. The purpose of these investigations was: "...to provide geologic and hydrologic information necessary to identify areas beneath the Hanford Site that have a high probability of containing basaltic rock suitable for a nuclear waste repository" (Refs. 1,2). Later, in 1978, the National Academy of Science (NAS) recommended that DOE consider the Rattlesnake Hills at Hanford, as a possible storage site for nuclear wastes (Ref. 15). The NAS surmised that a nuclear waste repository could be excavated between the perched water table, high in the hills, and the main water table.

DOE selected Hanford as a potential repository site primarily because of its land-use. Hanford is owned by the Federal government and has been committed to nuclear activities since 1943. After many years of commitment to nuclear activities, extensive portions of the Hanford Reservation would never be returned to unrestricted land-use; thus, Hanford is considered to be highly appropriate for continued equivalent use (BWIP-SCR). In addition, DOE had some technical reasons for selecting Hanford. Considerable geologic and hydrologic data has been gathered on the Pasco Basin. Much of this data is closely aligned with the objectives of finding a site for a nuclear waste repository (Refs. 2,3). Also, DOE maintains that the Pasco Basin's nearly uniform physical characteristics and thick basalt flows make it an attractive site for a repository (Ref. 5).

3.3.2 Staff's Analysis of DOE's Rationale For Selecting the Hanford Reservation

The NWTS National Siting Plan states that the first repository will be selected through either a land-use approach or a host rock approach. The Hanford Reservation was selected by the land-use approach. By using the land-use approach, DOE has by-passed two screening steps that occur when the host-rock approach to siting is used. When the host-rock approach is used, the screening program would pass through national and regional surveys before area surveys could begin. When a land-use approach is used, the site investigation begins with an area survey (see Figure ____, Appendix A).

National and regional surveys have led to several study areas. For example, investigations at the Paradox Basin alone have delineated four study areas: Salt Valley, Gibson Dome, Elk Ridge and Lisbon Valley. Since the land-use approach omits national and regional surveys in its screening process, there is only one study area. For the BWIP, this study area is the Pasco Basin .

If the BWIP-SCR is going to provide some basis for future National Environmental Policy Act (NEPA) decisions, DOE should have shown, in the SCR, how the Pasco Basin compares to other study areas, particularly those which are also dedicated to nuclear activities (e.g., land in South Carolina, Idaho, New Mexico and Nevada). The staff recommends that DOE makes this comparison in the BWIP-semiannual reports. As an alternative, DOE could compare the Pasco Basin area to study areas selected by the host-rock approach.

By comparing the Pasco Basin area to other study areas, DOE could confirm that Hanford is a reasonable repository site alternative for NEPA purposes. The NRC will be required to prepare an environmental impact statement (EIS) to support its decision to authorize the construction of a geologic repository. Under the provisions of the National Environmental Policy Act (NEPA) and the NRC procedural rule (46 FR 13973), the alternative repository sites, presented in the EIS, must be among the best that can reasonably be found. The staff feels that DOE should confirm that the Hanford Reservation is a reasonable alternative for a repository site before NRC begins its formal NEPA process.

3.4 The BWIP Site Screening Process

The BWIP site screening process begins at the Pasco Basin (1600 mi^2) and ends at the reference repository location (18 mi^2). Three objectives guide DOE's progression from large to smaller land areas:

- maximize public health as safety
- minimize adverse environmental and socioeconomic impacts
- minimize system costs

Before these objectives could be realized, some assumptions had to be made on how a repository would be constructed, how it would operate, and what impacts it may have. These assumptions are listed in reference 5.

Having established their objectives and made their assumptions, DOE prepared screening guidelines. (see p.p. 2.2-9 through 2.2-13 of the SCR) The guidelines where depicted on map overlays and applied in five steps to areas under study. Starting at the Pasco Basin, each step successively reduced the land area that would be considered in the following step. At the end of each step the following areas were defined:

Step 1 - Pasco Basin or study area (1,600 mi^2)
Step 2 - candidate area (several hundred mi^2)
Step 3 - subarea (approximately 100 mi^2)
Step 4 - site locality (up to 50 mi^2)
Step 5 - candidate site (approximately 10 mi^2)

The overlay process ended with nine candidate sites, all on the Hanford Reservation.* At this point in the screening program DOE discontinued using overlays and began a comparative evaluation of the candidate sites. Five attributes were used to provide a means of comparing and eventually differentiating among the sites. The attributes include:

- Distance to discharge areas
- Structural geologic considerations

- Site biologic impact
- Distance to potentially hazardous facilities
- Potential for repository expansion

These attributes were used to quantitatively measure a condition or charactristic of the candidate site by means of actual unit scale, such as distance or a constructed scale that quantified the conditions. For example, under the site attribute, "potential for repository expansion," a site condition which would allow expansion for say 6 miles would be given a higher value than one which allow expansion for 2 miles. In a similar fashion, all the conditions or characteristics for a particular candidate site were assigned a value, the values were totalled and the sites with the highest score were considered the most attractive. The results of the comparative evaluation of the candidate sites showed that the central portion of the Cold Creek syncline area (Figure ___, Appendix A) should be evaluated in the final screening phase.

The final phase of site-selection deliniated a reference repository location (18 mi^2) within the Cold Creek syncline area. Ranking criteria, analagous to the attributes used in the previous screening phase, were applied to each candidate site in the Cold Creek syncline area. The ranking criteria include:

- Structural geology
- Seismucity
- Geohydrology
- Man's activities
- Host rock characteristics
- Environment

*At one point in the site screening process, DOE evaluated 4 subareas (each approximately 100 mi^2) located outside the Hanford boundry but within the Pasco Basin. Three subareas were eliminated from consideration because of land use and hydrological conflicts. The remaining subarea was dropped because of conflicts in land use, hydrology, bedrock dip and tectonic stability. DOE concluded from this evaluation: "Because no area of the Pasco Basin outside of the Hanford Site was found to be obviously superior to areas within the Hanford Site, further study to identify (repository) site localities was concentrated on the subareas of the Hanford site." (Ref. 4)

Then the sites were ranked using an ordinal dominance analysis (see ref. 5 for details). The outer boundaries of the sites ranked highest incribed the reference repository location (Figure__, Appendix A).

3.5 Staff Analysis of the BWIP Site-Selection Process

As discussed in Section 3.4, DOE applied screening guidelines to the Pasco Basin to find nine candidate sites for a geologic repository. The SCR references a document that compares the BWIP screening guidelines to those recommended by the National Waste Terminal Storage Program (NWTS) (Ref. 13). This document, entitled Comparison of NWTS-33(2) Criteria and Basalt Waste Isolation Project Screening Considerations, RHO-BW-EV-IP, compares BWIP criteria with a draft version of the NWTS criteria (Ref. 12). The final NWTS document (Ref. 12) recommends several screening criteria which were not applied at BWIP. Specifically, the staff finds that the following NWTS criteria were omitted from the BWIP site-selection process:

- A site's geohydrology should:
  1. be compatable with retrival.
  2. minimize contact time between groundwater and waste.
  3. permit modeling.

- A site's geochemistry should have characteristics compatible with retrival.

- A site's resources, such as water, should be evaluated to assess the likelihood of human intrusion

- A site should be located such that risk to the population from transportation of radioactive waste can be reduced below acceptable levels to the extent reasonably achievable.

In selecting the reference repository location, DOE considered mineral deposits and transportation impacts, but not in sufficient depth. DOE should have evaluated water resources as well as mineral resources. Given the arid environment of the Pasco Basin and the expected agricultural growth, water resources may be a limiting factor when repository construction begins. DOE did not consider transportation guidelines until the locality phase of site screening. Transportation impacts, however, will not be limited to the locality of the proposed site, alone. High level waste must be transported across the nation to reach a repository at Hanford, Washington. The staff recommends that DOE evaluate transportation and water-use impacts during their detailed investigations at Hanford.

Even though BWIP did not use all of the NWTS screening criteria, the staff believes that the reference repository location is at least as good as any location within the Pasco Basin. Some of the NWTS criteria may be more appropriate for national and regional surveys and could not distinguish one site from another within Hanford's 620 mi^2 area. Nevertheless, BWIP should not omit any of the NWTS screening criteria without some explanation. Selective implementation of the NWTS criteria can create inconsistencies among repository investigations in different geologic media. For example, the Office of Nuclear Waste Isolation (ONWI), which is investigating domal salt for a potential repository site, is using different terminology than BWIP. In reference 14, an ONWI document, each of seven salt domes is called a "candidate site" while the same term does not appear in the BWIP program until DOE was fairly certain where the repository would be located. Likewise, reference 14 refers to a "repository location" but does not define its size. At BWIP a repository location can cover an area of up to 50 mi^2 (except for the reference repository location which covers 18 mi^2).

3.5 Staff Conclusion

Based on our review of the BWIP SCR and its supporting documents, the staff offers the following comments and conclusions regarding the DOE site selection process.

- The DOE did not adequately compare the Pasco Basin study area to other study areas selected by either the land-use or the host-rock approach (as described in the NWTS National Siting Plan). The staff feels that DOE should make this comparison, perhaps in the BWIP semiannual reports, before the NRC NEPA process begins. The study areas should be compared at the same level of detail as the area survey phase of characterization in the National Siting Plan. An early comparison of study areas will ensure that only reaonable alternatives will be considered during the licensing process.

- None of the other sites within the Pasco Basin that were evaluated by DOE in the SCR are preferrable to the reference repository location.

- Differences between the BWIP and NWTS siting criteria can be attributed to the different geographic starting point for the host-rock and land-use siting concepts. The differences do not indicate that the NWTS and BWIP site-screening guidelines are inconsistant or that the BWIP guidelines were ineffective. the differences will, however, complicate a comparison between BWIP and repository projects which have followed the NWTS guidelines more closely.

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4 GROUNDWATER

4.1 General Discussion

DOE has provided a description of the hydrogeologic system(s) within the Pasco Basins in Chapter 5 of the SCR. The conceptual model of groundwater flow is incorporated into a numerical groundwater model and the numerical model is exercised using selected values from the BWIP data base to determine flow paths and to calculate hypothetical travel times in Chapter 12 of the SCR. DOE's issues and plans for hydrogeology are presented in Chapter 13; issues and plans for performance assessment, including numerical modeling of groundwater, are presented in Chapter 16 of the SCR.

The importance of understanding the groundwter systems of the Hanford site is stated clearly by DOE:

> "It is generally recognized that the most probable mode by which radionuclides could be released from a repository facility is thorugh the groundwater system" (SCR, p. 12.1-1).

Principal portions of proposed 10 CFR 60 which would require evaluation of the hydrogeologic system at time of licensing include:

> 10.112 Overall System performance Objective - This section requires that release to the accessible environment meet standards set by the EPA.
>
> 60.113(a)(2) Geologic Setting - This section requires preemplacement groundwater travel times from the disturbed zone to the accessible environment exceed 1,000 years.
>
> 60.122 Siting Requirement - This section lists various favorable and potentially adverse conditions which will require hydrogeologic evaluations.

4.2 Summary of Conclusions and Assertions in the SCR

Aspects of the hydrogeologic system which are described in the SCR include:

- A conceptual model of the hydrogeologic system
- Hydraulic parameters (horizontal hydraulic conductivity, effective porosity, and dispersivity)
- Hydraulic heads
- Hydrochemistry
- A numerical groundwater model.

The groundwater flow systems in the basalts are characterized by DOE as follows (SCR, 5.1-198-203):

"The flow systems in the basalts are confined."

"Lateral groundwter movement occurs within sedimentary interbeds and flow tops."

"Vertical groundwater leakage between different permeable zones takes place across the interiors of basalt flows."

"The principal confining units in the basalts are the low-permeability columnar zones of individual basalt flows."

"The presence of interbeds has no discernible influence on vertical-head distributions."

"Little vertical groundwater mixing is occurring between shallow and deep flow systems in non-structurally deformed areas."

"Some vertical groundwater mixing is believed to take place along major geologic structures such as the Umtanum Ridge-Gable Mountain anticline."

"The structural discontinuity trending north between the Cold Creek Valley and the reference repository location has a significant influence on local hydraulic heads and, therefore, groundwater-flow directions."

"The overall groundwater flow direction for both shallow and deep basalts in the Cold Creek syncline is toward the southeast."

"The principal discharge area for the deep basalts is still suspected to be south of the Hanford Site."

The conceptual model outlined by DOE has been incorporated into a numerical groundwater model which is used to determine flow paths and to calculate travel times. Based on the performance assessment modeling noted in the SCR and earlier modeling efforts, DOE asserts that:

> "Even with the different assumptions used, and in light of different organizations performing these analyses, the pre-waste-emplacement travel times calculated to date significantly exceed the 1,000-year travel time from the repository to the accessible environment in the NRC proposed regulations (NRC, 1981)" (SCR, p. 12.4-51).
>
> "With regard to waste isolation effectiveness, the results of the near-field performance analysis support the following conclusions:
>
> - The post-waste-emplacement groundwater travel times from the repository to the reference boundary (10 kilometers from the edge of the repository) are estimated to be greater than 10,000 years, ignoring the travel time through the engineered barriers.
> - The groundwater flow paths from both candidate repository horizons are predominantly horizontal and are restricted to the Grande Ronde Basalt" (SCR, p. 12.4-51).
>
> "Studies conducted to date by Rockwell and other independent organizations unanimously agree that the minimum travel time from the repository to the accessible environment under natural, pre-waste-emplacement conditions is likely to be on the order of 10,000 years or longer. As a result, considerable confidence exists that compliance with the 1,000-year minimum travel time to the accessible environment specified in NRC proposed technical criteria will be demonstrated for the reference repository location" (SCR, p. 12.4-53).

Based upon the review and preliminary evaluation of the SCR conducted by the NRC staff, the above assertions and conclusions appear to be premature.

4.3 Discussion of Selected Issues

The master list of issues is presented in Appendix C, in which DOE and NRC issues are compared. Groundwater issues identified by the NRC compare favorably with work elements described by the DOE in Chapter 13 of the SCR. However, the NRC staff seriously questions whether the proposed work plans outlined in the SCR will be appropriate and sufficient to resolve major groundwater issues by the time of application for construction authorization.

Analysis of each of the issues identified in Appendix C has been prepared by the NRC staff and is located in Public Document Rooms. These Site Issue Analyses (SIA's) have been developed based on staff review of the SCR and supporting documents and the on-site reviews conducted within the last two years. Selected issues of major significance are discussed below.

4.3.1 Conceptual Groundwater Models

Issues related to conceptual groundwater models at the Hanford site are analyzed in SIA 1.1.7. DOE's conceptual groundwater model, as presented in the SCR, is based on a geologic system which consists of areally continuous layered basalt flows and interbeds of the Columbia River Basalt Group. DOE asserts that the flow systems are confined, with interbeds and flow tops acting as horizontal aquifers and low-permeability columner basalt zones acting as confining layers. While DOE recognizes that vertical leakage potentially occurs across flow interiors, strong assertions are made in the SCR that suggest that little vertical mixing occurs between shallow and deep flow systems in undeformed areas. Some vertical mixing is believed to occur along major geologic structures, particularly to the north of the RRL. The SCR further assets that the overall groundwater flow direction in the basalts is to the southeast and that the principal discharge area is to the south of the Hanford site.

DOE has placed major emphasis on the concept that the hydrochemistry of groundwater defines separate shallow and deep flow systems. NRC staff finds from a preliminary evaluation of the hydrochemical data in the SCR and other available data that any conclusive definition of separate flow systems is questionable and clearly premature (Appendix F). While hydrochemical data can provide useful supportive information, primary evaluation of the flow system must be based on the hydraulics of the flow system. The hydraulics can be better defined by further geologic information (Appendix O), the results of large-scale hydraulic testing (Appendix E), and accurate measurements of hydraulic head (Appendix G).

NRC staff also finds that the conceptual model presented in the SCR depends heavily on information from wells DC-6, DC-14, and DC-15, which are located far from the RRL. Data from well RRL-2, DC-13, and other wells near the RRL are not considered in the development of DOE is conceptual model. Perhaps more fundamentally, the basic inputs needed for the model - hydraulic parameters, hydraulic heads, and hydrogeologic boundaries, including both external boundary conditions and internal hydrogeologic discontinuities - are so uncertain that several alternative conceptual models can be formulated based on the present state of knowledge (Appendix O). In addition to DOE's model of an areally continuous layered system with very low vertical leakage, the NRC staff recommends that the following four conceptual models deserve consideration by DOE (Appendix O):

1. An areally continous layered system with high vertical leakage.

2. An areally discontinuous layered system with high vertical leakage distributed areally in a manner which produces the hydraulic equivalent of a large-scale, homogeneous, anisotropic system.

3. An areally discontinuous layered system bounded by low permeability structures.

4. An areally discontinous layered system bounded by high permeability structures.

NRC staff finds that the hydrogeologic setting of the Hanford site is such that large-scale hydraulic testing can effectively evaluate the groundwater system (Appendix E). Such tests would greatly decrease uncertainty about basic hydrogeologic parameters and could be used to test directly many of the possible conceptual groundater models.

4.3.2 Hydraulic Parameters

Issues relating to the measurement and interpolation of hydraulic parameters are included in SIA's 1.1.1.1 and 1.1.1.2. The absence of state-of-the-art multiple-hole pump-test measurements of hydraulic parameters and the absence of any measurements of vertical hydraulic conductivity are of major concern with respect to areal hydraulic continuity, determination of flow paths, and consequent travel time calculations. Single-hole tsts of horizontal hydraulic conductivity are essentially point tests which do not describe adequately the bulk hydraulic conductivity of the unit tested. Furthermore, the SCR indicates no correction applied to hydraulic conductivity tests for the effects of drilling mud ("skin effect"), which often yields hydraulic conductivity values that are too low (Appendix I). Effective porosity and dispersivity have been measured in only one test interval at the site. Matrix diffusion has not been measured, though the effects on radionuclide transport may be significant (Appendix F).

Of the major hydraulic parameters, vertical hydraulic conductivity, horizontal hydraulic conductivity, effective porosity, dispersivity, and matrix diffusion, only horizontal hydraulic conductivity has been measured at more than one location and in more than one test interval; two of the five parameters, vertical hydraulic conductivity and matrix diffusion have not measured at all. In light of the extreme uncertainty inherent in such a limited data base, the NRC staff vehemently disagrees with DOE that a high level of confidence can be applied to a conceptual groundwater model which depends critically on assumptions about vertical hydraulic conductivity and effective porosity.

Another major related concern is the method by which measured hydraulic parameters are interpolated to describe the properties of numerical modeling units. Available data indicate extreme variations in measured parameters (i.e., of horizontal hydraulic conductivity) which do not allow reliable interpolation of values, even by geostatistical techniques (Appendix H).

The NRC staff finds that the uncertainties in the values of hydraulic parameters presented in the SCR are much too great to assign credence to any conceptual or numerical model which depends on these data in their current condition. In particular, travel time calculations cannot be made with any degree of confidence.

On the other hand, the staff believes that large-scale pump tests with multiple observation wells can be designed, run and analyzed to provide much of the information required to characterize and ultimately model the BWIP site (Appendix E).

4.3.3 Hydraulic Head

Issues related to hydraulic head are discussed in SIA's 1.1.1, 1.1.2, 1.1.3, 1.1.7, and 1.1.8. The distribution of hydraulic head at the site leads to multiple interpretations of groundwater flow systems. It is not clear whether the complex distribution of hydraulic head is a product of measurement error associated with packer technology (Appendix G) or is a product of the existence of a very complex flow system at the Hanford site (Domenico, Ford and others, 1981, p. VI-9). For example, the SCR (Table 5-9) states that the hydraulic gradient between RRL-2 and DC-15 is toward the southeast. The gradient between DC-12 and DC-15 is stated correctly to be toward the southeast also. The 3 wells are very nearly colinear in plan. But comparison of heads between wells DC-12 and RRL-2 reveals that the gradient is to the northwest (toward the repository). In fact, gradients in all geologic units between wells DC-12 and RRL-2, wells DC-16A and RRL-2 and wells DB-15 and RRL-2 are toward the repository. Accurate knowledge of hydraulic head is needed to define boundary conditions for, to calculate hydraulic gradients for, and to calibrate numerical models. The errors introduced by DOE's misuse of hydraulic-head gradient data in the conceptual and numerical models of the SCR lead to not only inappropriate flow paths, but also to incorrect estimates of travel time.

NRC staff finds that long-term head-monitoring devices can be installed and used to obtain the reliable hydraulic head data which are essential to formulating credible conceptual and numerical groundwater models.

4.3.4 Hydrogeologic Boundaries

Issues related to hydrogeologic boundaries are considered in SIA's 1.1.2 to 1.1.8. Knowledge of both external and internal hydrogeologic boundaries is critical to developing and interpreting conceptual and mathematical groundwater models. In the absence of reliable hydraulic head data (4.3.3), external boundary conditions cannot be specified with any degree of confidence.

The NRC staff finds that internal hydrogeologic boundaries, which include potential structural and stratigraphic discontinuities, have not been adequately tested in the field by DOE nor adequately considered in formulating and refining groundwater models. DOE's conceptual model of areally continuous layered flows and interbeds (4.3.1) gives no consideration to stratigraphic discontinuities, although regional stratigraphic relationships suggest that they may be significant (Appendix O). Similarly, the DOE conceptual model does not take into account the structural discontinuities (SCR, Chapter 3) which might disrupt the layered flow system. The DOE has reported (SCR, Chapter 3) that discontinuities may range in scale from the columnar fracture of inverted fans to major fault zones of the scale of Gable Mountain-Untanum Ridge structure; that the structures may be high permeability or low permeability discontinuities; and that the discontinuities are not necessarily perpendicular to the stratigraphy. Because DOE has not tested any internal hydrogeologic boundaries, the SCR contains no real data which can be used as input for numerical modeling of the effects of structural discontinuities on groundwater flow paths or travel times. The DOE also recognizes the potential importance of such factors:

"The occurrence of such dimples is particularly significant because the relatively porous nature of the flow top combined with the well-developed columnar fractures of the inverted fans may significantly reduce the amount of hydrologic isolation provided by the host flow itself" (SCR, p. 3.5-32). The performance assessment modeling of the SCR (Chapter 12) considers only one case of structural discontinuity, a major high-angle fault which extends from the repository horizon to the Vantage interbed. The NRC staff is very concerned that while DOE has recognized the potential importance of other potential structural discontinuities, they have neither tested them in the field using state-of-the-art hydrologic tests (Appendix E), nor adequately considered them in formulating conceptual or numerical groundwater models.

4.4.5 Mathematical Groundwater Models

Issues related to mathematical groundwater modeling are analyzed in SIA 1.1.8. DOE has made conclusive predictions of groundwater (flow paths and trave times) based on numerical modeling. The NRC staff believes that the computer code (PORFLO) used by DOE to determine flow paths and to calculate travel time is an acceptable two-dimensional code. However, the staff finds that the results of the numerical modeling lack any degree of confidence and are premature. The staff notes that this type of mathematical groundwater modeling is essentially an exercise in solving boundary-value problems. Reliable solutions to any boundary-value problem require an accurate representation of the physics of the flow system (i.e., an accurate conceptual model), the appropriate differential equations, and reliable input data. The form of the governing equations is not in dispute. However, the NRC staff has major concerns with DOE's conceptual model (4.3.1), with the nature and description of boundary conditions (4.3.4), and with the basic hydraulic data used in solving the equations (4.3.2). Furthermore, the staff finds that because of the unreliable nature of the hydraulic head data (4.3.3), the particular numerical model used by the DOE (SCR, Chapter 12) is not calibrated and cannot be calibrated. In short, the variability and/or uncertainty in hydraulic parameters and hydraulic head, and the uncertainty of proposed hydrogeologic boundary conditions make the use of this numerical groundwater model by DOE so unreliable as to be worthless for <u>predicting</u> groundwater flow paths and travel times with any degree of confidence.

The NRC staff also finds that the geology and hydrogeology of the Hanford site are very favorable for a program of physical testing of the flow system (Appendix E). A program of large-scale pump tests using multiple observation wells would provide much of the data needed to test alternative conceptual models and to supply reliable boundary conditions and hydraulic parameters for a numerical model.

The NRC staff finds that the current DOE numerical groundwater model can satisfactorily be used for identifying areas of uncertainty and for evaluating proposed strategies for mitigating uncertainties.

4.4 Evaluation of DOE's Plans and Program

Evaluations of DOE's plans and program for each of the NRC groundwater issues is given in SIA's 1.1 to 1.6. This section of Chapter 4 deals only with evaluations of DOE's plans and programs for issues of major significance identified in Section 4.3.

4.4.1 Conceptual Model

DOE proposes to refine the conceptual model using data from a confirmation of their present program of relatively small-scale hydrogeologic testing.

The NRC staff finds that DOE's plans do not adequately address alternative conceptual models. The testing program is inherently limited by its over-reliance on DOE's current conceptual model. In particular, the DOE program is not designed to take advantage of the testability of the Hanford hydrogeologic system to run objectivity physical tests of plausible alternative conceptual models.

4.4.2 Hydraulic Parameters

DOE plans to collect new data on hydrualic conductivity, effective porosity, and dispersivity through tests in 30 single boreholes, 4 dual boreholes, and 2 cluster holes. Some of these tests are contingent on DOE's ability to rehabilitate existing boreholes which have various construction problems. Only one of the proposed cluster tests (DC-16A, B, C) is located near the RRL, and the scale of the test is small with respect to the dimensions of the RRL, the Cold Creek Syncline, and the controlled area.

The NRC staff finds that the proposed test program is merely a continuation of the program used to collect data for the SCR. DOE still has no plans to test matrix diffusion (Appendix F). Because of the extreme variability of parameters in the existing data base (Appendix H) and problems associated with the drilling and testing methods used by DOE (Appendix I), the NRC staff does not have confidence in the reliability of the current values of hydraulic parameters. The staff also has a major concern that the continued reliance of DOE on small-scale hydrogeologic testing is not likely to improve the reliability of the data on hydraulic parameters needed for conceptual and numerical models of the groundwater system at Hanford.

4.4.3 Hydraulic Head

DOE proposes to continue collecting point measurements of hydraulic heads during the drill-and-test sequnce using the packer technology. The SCR indicates that DOE is assessing the need for time-variant measurements.

Accurate knowledge of hydraulic heads is a critical component in formulating reasonable conceptual models and in calibrating numerical models (4.3.3). The NRC staff finds that point measurements of hydraulic heads made during the drill-and-test phase of the program are inaccurate and inadequate (Appendices G and H). The current head data are not sufficient to reliably define even the direction of groundwater flow (wells RRL-2 - DC-12 - DC-15, See 4.3.3).

4.4.4 Hydrogeologic Boundaries

DOE plans to use a cluster test around the McGee well to test the nature of the apparent hydrogeologic boundary west of the RRL, and to use new borehole DC-18 to test the Gable Mountain-Untanum Ridge structural zone, using unspecified single-hole techniques. No specific plans are persented to test other possible hydrogeologic boundaries.

Hydrogeologic boundaries cannot be adequately investigated by geologic means. The conventional method of testing is with large-scale pump tests with multiple observation wells (Appendix E). In the absence of a systematic, state-of-the-art testing program for hydrogeologic boundaries, the NRC staff believes that it will be impossible to properly evaluate conceptual or mathematical groundwater models.

4.4.5 Mathematical Groundwater Modeling

DOE plans to verify and benchmark the computer codes used in modeling. DOE plans to use data and mathematical modeling intentively in parametric and sensitivty studies as a guide to model input. DOE recognizes that they may need to develop stochastic models to bound the predictive certainty indicated by the current deterministic models.

The NRC staff believes that computer code development is proceding appropriately. However, DOE has no apparent plans to numerically model alternative conceptual models. Furthermore, the NRC staff reiterates its position that the numerical models represent boundary value problems, and that reliable results must be based on valid conceptual models, boundaries, and inputs.

4.5 Recommendations on Gaps in DOE's Program to Resolue Key NRC Issues by Licensing Time

Based on analysis o the data and plans presented in the SCR, the NRC staff finds that the following major gaps need to be resolved by licensing time:

1. Lack of bulk hydraulic parameter values.

2. Lack of large scale hydrologic tests of the flow systems. Such tests would permit objective evaluation of DOE's conceptual model, would provide hydraulic parameters, hydraulic heads, and information on hydrogeologic boundaries, and would permit calibration of the numerical model.

3. Lack of long-term hydraulic head monitoring.

4. Lack of matrix diffusion data, which may be important to transport modeling.

5. Lack of a mathematical model which will be used to help characterize the hydrogeologic system by testing alternative conceptual models as well as assessing systems performance.

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5 GEOLOGIC STABILITY

5.1 General Description

5.1.1 Geologic Stability Information in the SCR

As required in 10 CFR 60 (proposed), Chapter 3 of the SCR summarizes the status of geologic investigations at the BWIP site. These investigations, aimed at defining the geologic setting, the present geologic processes operating in the Pasco Basin and the long-term geologic stability of the BWIP site include: rotary and cored boreholes, physiography, geomorphology, stratigraphy, geophysics, structural geology and tectonics, long-term regional stability, and mineral resources. Chapter 13 of the SCR summarizes elements of work needed to resolve outstanding issues.

5.1.2 Key Elements of Geologic Stability in 10 CFR 60

10 CFR Part 60 states that "the nature and rates of tectonic, hydrogeologic, geochemical, and geomorphic processes (or any such process) operating within the geologic setting during the Quaternary Period, when projected, would not affect nor would favorably affect the ability of the geologic repositiory to isolate the waste.

5.2 Summary of Main Conclusions and Assertions in the SCR

The two critical issues (with work elements) identified in the SCR are:

- What are the geologic, mineralogic, and petrographic characteristics of the repository horizon and surrounding strata within the RRL (S.1.A).

- What are the nature and rates of past, present, and projected structural and tectonic processes within the geologic setting and the RRL (S.1.B).

Investigations that DOE states have satisfied regulatory criteria are:

- Determine the nature of igneous activity within the Pasco Basin area (S.1.23.B).

- Determine the potential for, and effect of, failure of existing or planned man-made surface water impoundments (S.1.44.D.).

- Evaluate the effect of possible climatic changes (S.1.49.D).

- Determine whether the range of geomorphic conditions since the start of the Quaternary Period indicates instability from a waste isolation standpoint (S.1.60.D).

- Determine the likelihood of repository exhumation due to extreme erosion over the next 10,000 years (S.1.61.D).

5.3 Discussion of Critical Issues in 5.2

The critical issues (S.1.A and S.1.B) in geology and long-term geologic stability identified in Chapter 13 of the SCR are consistent with the prime issues identified by the staff in site issue analyses 5.1, 5.2, 5.3.1, and 5.3.4 (see Appendix C).

Stratigraphic and structural discontinuities (Site Issue Analysis (S.I.A. 5.1, and 5.2) will impact facility design, constructability, groundwater inflow into shafts and drifts, and regional groundwater flow (refer to S.I.A. 1.1.4 and 1.1.5). Preliminary conclusions on the occurrence of stratigraphic and structural discontinuities in the Columbia River Basalts in the Cold Creek Syncline are based on limited outcrops and widely spaced borings. The occurrence of thick flowtop breccia and a correspondingly thin dense interior in the Umtanum

Flow in boring RRL-2 points to the lack of stratigraphic control in the Grande Ronde and specifically in the Umtanum Flow. Other stratigraphic discontinuities such as flow-pinchouts, vesicular zones, and fanning joints are equally difficult to characterize. Subtle structural discontinuities (fault/fracture zones) have not been adequately characterized by investigations completed to date. Geologic investigations have been aimed at identifying inferred major structures bounding relatively intact blocks of rock (C. W. Meyers, 1981).

Recent deformation and (S.I.A. 5.3.1 and 5.3.4) are indicative of potential tectonic instability. Preliminary data on strain rate, seismicity, and faulting suggest that the Pasco Basin is relatively geologically stable (SER, WNP-2, NUREG-0892, 1982; RHO-BWI-ST-14), therefore catastrophic tectonic processes, such as volcanism (flood basalts, dike injection, volcanoes), major faulting and earthquakes ($\geq M_s$ 6.5) are unlikely. Several lines of evidence are, however, indicative of ongoing tectonic activity such as microearthquake swarms, displacement of late Pleistocene sediments along the Rattlesnake-Wallula (RAW) alignment, historic seismicity on faults associated with east-west trending folds (Toppenish Ridge), and Pleistocene displacements along faults at Gable Mountain. Faulting/fracturing and associated seismicity may impact respository performance by 1) damage to the engineered system and 2) altering groundwater flow paths.

5.4 Evaluation of SCR Plans and Programs

Planned geologic and geophysical investigations will not characterize the stratigraphic and structural discontinuities of the Columbia River basalts in the Cold Creek Syncline. The predictability of the these features is low. Data collected from outside the Pasco Basin, north of Vantage, will be of limited use in predicting the occurrence of similar features at depth in the controlled zone. Testing in the exploratory test facility will not characterize the lateral continuity of the potential host rocks, the strata above and below, or the structural discontinuities. The impact of these discontinuities on groundwater flow must be assessed through appropriate hydrologic testing (see Chapter 4). The majority of existing borings were located away from structure

(RHO-BWI-ST-4) in order to develop accurate stratigraphic control. The limited number of additional borings planned will not sufficiently characterize stratigraphic and structural discontinuities.

Planned investigations to evaluate the regional structural and tectonic setting of the Pasco Basin lack the level of detail necessary to evaluate the adequacy of the plans. Review of existing regional geologic data (S.1.11.B) should have been largely completed during site screening. General data summarized in Chapter 3 of the SCR is, in many respects, not current, i.e., does not take into account recent findings of WNP-2 and Skagit power plant investigations (NRC 1982).

Shallow geophysical studies completed at Gable Butte and the Eastern end of Yakima Ridge (Cochran, 1982a, Cochran, 1982b) indicate that subsurface structure can not be equivocally interpreted without borehole control. No plans to obtain borehole control to ground truth the geophysical interpretations were presented in Chapter 13 of the SCR.

5.5 Recommendations

- Hydrologic testing (Chapter 4) must be completed to determine the effects of structural and stratigraphic discontinuities on groundwater flow. These discontinuities cannot be completely characterized by geologic and geophysical investigations.

- Other structural studies should be factored into DOE's structural studies. Semi-quantitative balanced cross-sections, producted in response to USGS questions for WNP-2, support a model of primary low angle thrust faulting with 1-2 km of horizontal displacement that may project into the RRL. Thess data contradict Price's (1982) tectonic model. Modeling of a series of profiles from aeromagnetic data (Weston Geophysical), accross and between, the brachyanticlines SE of Rattlesnake Mountain (RAW), show identical signatures and are aligned so that "the interpretation of a linear, throughgoing fault is difficult to avoid" (USNRC 1982, 2-16). The data impacts the evaluation of fault continuity along RAW.

- There are no explicit plans to assess the possibility of a seismic event as large as Ms = 6.5 on RAW, to investigate microearthquake triggering mechanisms in the controlled zone, or for determining the size and frequency of structures (faults, fractures) on which earthquake swarms occur.

- With the exception of the investigation of the Nancy linear, there are no planned geologic borings to investigate known or inferred geologic anomalies. Planned geologic and geophysical investigations along Yakima Ridge are lacking although this fold, and its buried extension, is in close proximity to the RRL.

- No regional geologic map is included in the SCR.

CHAPTER 6 - GEOCHEMISTRY

6.1 General Discussion

6.1.1 Introduction

The most likely means of transport of radionuclides from a HLW repository to the accessible environment is transport in solution by groundwater. As the radionuclide-containing leachate moves through the near-field and far-field rock environment it will interact with rock/water conditions that, in turn, will change the speciation and solution concentration of the radionuclides and thus affect their migration behavior. Hydrothermal interactions controlled by geochemical reactions and kinetics will control the near-field host environment. Geochemical reactions and kinetics at ordinary temperatures will control the far-field host rock environment. Thus, the effect of geochemical parameters on radionuclide migration is an important element in performance assessment modeling of radionuclide release to the accessible environment.

6.1.2 NRC Technical Criteria (10CFR60 Subpart E)

Relevant sections of draft NRC Technical Criteria (10 CFR 60 subpart E) are:

1. 60.113(2)(3)
2. 60.122(b)(1)
3. 60.122(b)(4)
4. 60.122(b)(5)
5. 60.122(c)(9)
6. 60.122(c)(10)
7. 60.122(c)(11)
8. 60.122(c)(21)

6.2 Summary of Geochemistry in the SCR

The geochemical information presented in the SCR are the aggregated results of preliminary investigations and general plans for characterizing (1) site specific groundwater-rock (basalt) alteration reactions, (2) reactions among the materials used in the engineered waste package, (3) dissolution reactions of waste forms, (4) concentrations limits imposed on selected dissolved radionuclides by solubility constraints, and (5) selected radionuclide precipitation and sorption reactions in both the near-field and far-field environments. No specific plans for conducting the investigations such as experimental assumptions, experimental design, experimental methods or approaches to data analysis are given (as was suggested in the SFCG - Regulatory Guide 4.17).

Based on preliminary scoping studies consisting of limited site specific experimental evidence and the review and reference to selected off site work, the following preliminary working assumptions were suggested:

1. The prevailing Eh environment at Hanford estimated to be of low oxidation potential (reducing), and the Eh environment, after waste emplacement and closure, is estimated to quickly return to a low Eh environment,

2. Radionuclide release is, in most cases, solubility controlled, not leach rate limited,

3. In the in situ groundwater environment likely, the backfill, host rock and fracture filling minerals have a high sorptive capacity for released radionuclide species,

4. That the pH of the rock water system is buffered by silica dissolution to a range that is between 8.8 to 10.1,

5. That mineralogy of the likely backfill and the host rock and fracture-filling is subject to little or no permanent alteration due to waste emplacement,

6. Based on geochemical date, ther is no mixing of groundwater between aquafers,

7. Retardation of radionuclides can be accounted for by Kd isotherm data in solute transport codes,

8. Analogs of waste form, canister, overpack, backfill and repository suggest that hazards from HLW in repositories should be minimal, and

9. Diffusional processes control Eh/pH.

In order to validate the foregoing preliminary assumptions the following questions were established by DOE to generate specific experimental strategies and issues:

1. What are the geologic, mineralogic, and petrographic characteristics of the candidate repository horizons and surrounding status within the reference repository location?

2. Do the very near-field interactions between the waste package and its components, the underground facility, and the geologic setting compromise waste package or engineered system performance?

3. Are the geochemical and hydrologic properties of the geologic setting sufficient to meet NRC proposed requirements?

4. What is the relative importance of the waste form leach rate versus solubility of key radionuclides in the near-field environment for controlling release?

5. Can valid Eh measurements for the candidate repository horizons in the reference repository location be made either by potentiometric measurement or indirectly by measurement of dissolved redox couples?

6. To what degree does the geologic setting retard migration of key radionuclides from the engineered system in meeting U. S. Environmental Protection Agency draft release criteria?

7. How can very near-field waste/barrier/rock meterials interaction data, as measured experimentally, be extraploated over time to reasonably assure that overall waste package and repository performance meets regulatory criteria?

Based on the foregoing questions, a detailed list of work elements were developed as a strategy for site characterization. However, detailed plans for pursuing the work elements have not been defined in the SCR.

6.3 Summary of NRC Major Issues In Geochemistry

The major geochemical issues identified by the NRC for the Hanford site are related to the following questions:

1. What is the expected solubility of released radionuclide species in the near-field and the far-field through time?

2. What is the expected retardation of released radionuclides in the near-field and the far-field through time?

3. How is the migration behavior(including solubility and retardation) of radionuclides being validated and verified?

4. How are the geochemical data that have been and will be gathered be shown to be appropriate for use in anticipated performance assessment models?

5. What is the mineralogy/petrology/chemistry of the backfill before and after emplacment?

6. What is the mineralogy/petrology/chemistry of the nearfield/farfield host rock before and after to waste emplacment?

7. What is the mineralogy/petrology/chemistry of secondary minerals of the nearfield/farfield host rock before and after to waste emplacement?

8. What are the geochemical conditions expected under anticipated and unanticipated repository scenarios at the outer-waste-package interfaces with the host rock/backfill, in the near-field and in the far-field, through time?

9. What are the geochemical reactions (including thermochemical reactions) expected under anticipated and unanticipated repository scenarios from the outer waste package interfaces with the host rock/backfill, through the near-field and the far-field, through time?

In general, these issues are aimed at defining:

1. What are the (geochemical) environmental conditions of the waste package and released-waste initially, and as they change with time?

2. What are the conditions and processes affecting radionuclide retardation, in the nearfield and the farfield through time?

6.4 Analysis of Selected Major Issues and Plans

NRC issues and BWIP SCR issues are similar in that major issues (questions) concern investigations involving the definition of Eh/pH (hydrochemical) conditions, and the processes of speciation, solubility and sorption. By implication, the BWIP approach to the development of geochemical data needed for the resolution of issues appears to be well targeted. However, a detailed description of experimental strategy and analytical techniques was not provided. In addition, conclusionary statements concerning the status of geochemical consideration are seldom referenced. Further, conclusions, when referenced, are broad generalization or extrapolations based on very narrowly conceived and executed research results. Also, field measurements that do not fit repository conditions preconceived necessary are deemphasized in favor of calculational procedures that give "acceptable" answers. Finally, there is little discussion concerning the methods of assessment of uncertainties on existing data or data to be obtained. Thus, in general the geochemistry discussions in the SCR, as presented, are not technically sound.

6.4.1 Solubility Constraints

A major mechanism for controlling release of radionuclides from a repository in basalt is the precipitation or incorporation of radionuclides into new mineral phases, i.e., solubility contraints (See Appendix U). However, solubility is dependent on environmental conditions such as Eh, pH and groundwater composition. Specific DOE plans to identify and evaluate solubility constraints include:

1. Continue experiments on the interactions between the waste form, basalt and groundwater over the temperature, pressure, and Eh-pH conditions expected for the repository,

2. Use of data supplied by other laboratories from long-term static and low flow rate dynamic leach tests on simulated spent fuel and borosilicate glass,

3. Experimentally identify the dominant radionuclide species in basalt groundwater, and evaluate conditions that could lead to radionuclide colloid formation and subsequent particulate transport, and

4. Investigate the possible effects of the radiation field on radionuclide geochemical behavior.

There is however, inadequate discussion of the following:

1. The experimental and analytical techniques to be used in order to determine solubilites,

2. What Eh (redox) conditions are being considered in experiments.

3. The validity of the "expected repository condition" chosen,

4. Which radionuclide compounds are to be studied in the solubility experiments. In addition, it is not clear whether single species will be examined one at a time, multispecies will be examined (important for determination of possible synergistic effects) or both,

5. What strategy will be used to determine of the speciation of critical radionuclides (calcualtions to date have considered only simple oxide species),

6. The types of colloids expected to form (e.g., oxides, hydroxides, oxyhydroxides, organics (colloids can form from solution as the result of oversaturation or from physical and chemical degradation of the basalt and waste package),

7. The expected influence of the radiation field on radionuclide behavior at high P-T,

8. The methods of determining transferability of BWIP data and data generated by other labs trying to simulate the in situ conditions of the basalt repository to actual repository conditions,

9. The methods of assessment of uncertainties of existing data or data to be obtained,

10. What is to be done to develop computational schemes required to address solubility, speciation, and colloidal transport in a complex fluid flow regime.

11. The BWIP QA/QC program for geochemistry.

6.4.2 Sorption

Another mechanism for removing or retarding the movement of radionuclides in groundwater is the sorption of radionuclides onto basalts, secondary minerals, sedimentary rocks or engineered barrier materials contacted during groundwater movement through the Hanford controlled zone (See Appendix T).

Preliminary sorption work at RHO deals primarily with batch sorption experiments carried out under oxidizing conditions; therefore, many of the distribution coefficients and the sorption isotherms given contain values relevant only to oxidizing conditions. This problem was addressed briefly through the use of hydrazine to lower the Eh during some of the experimental runs. However, hydrazine is not an expected repository constituent and no discussion of the dissociation of hydrazine hydrate and experimental complications due to the possible sorption of the hydrate or possible complex ion formation was presented.

No discussion of multiple speciation and its effects on both the distribution coefficients and sorption isotherms has been presented. Batch sorption experiments give valid distribution coefficients only if a single radionuclide species dominate in the test solution (See Appendix T). Actinides, as well as fission products such as technetium and selenium, are notorious for simultaneously displaying more than one species in solution. Different species may exhibit very different sorption behavior and under such conditions the measured distribution coefficient is an average of the values for the different species, weighted by the quantities of the species present.

6.4.4 Redox Potential (Eh)

The redox potential (Eh) effects radionuclide solubility and sorption since it determines the stable state of the radionuclides entering the groundwater system. Under reducing (low Eh) conditions the solubility of most relevant radionuclides is lower and the formation of positively charged species is favored rather than the positively charged species formed under oxidizing conditons (See Appendix S). Measured Eh values in Grande Ronde basalt groundwater range from -0.22 to +0.21. But DOE staff considers these determinations imprecise, particularly the positive values, even though oxygen has been detected in some groundwater samples and the oxidation of the sulfide in pyrite has been cited as a likely source of sulfate (SO_4^{2-}) found in the groundwater system. In addition, as presented, BWIP redox calculations are based on questionable assumptions that iron bearing minerals in the host rock control redox potential and yield predicted Eh values near -0.45 volts. However, the calculated Eh values, based on mineral assemblages, have not been verified. For example, the magnetite-pyrite couple is assumed to buffer the basalt groundwater system Eh. For this couple to be valid for establishing the Eh throughout the repository, both magnetite and pyrite must be common minerals throughtout the basalt deposit in close proximity to each other and in contact with the groundwater. It is well established that the magnetite is a primary phase in Grande Ronde Basalt. Pyrite, however, is reported to occur as a rare secondary mineral along cooling joints and in fractures. Until evidence for the wide-spread existence of pyrite can be established (or the existence of some other couple) repository Eh conditions while possibly reducing, are not established.

6.4.5 Stability of Solid Phases (Rock Minerals, Volcanic Glass)

The general mineralogy, petrography and chemistry of the Grande Ronde basalt are known, with the exception of flowtops and interbeds. Except by inference, the various DOE work elements do not include determination of interbed materials.

The relative stabilties of montmorillonite and illite under the expected repository conditions needs confirmation. Illite does occur in the Grande Ronde basalts indicating a long term stability. It might be expected that dissolution of potassium-rich mesostasis (at elevated temperatures) could increase the stability of illite over montmorrillonite in altered basalts and lead to the alteration of the bontonite backfill to illite, thereby reducing its sorptive and swelling capacity. (See Appendix U)

6.4.6 Uncertainity Assessment

6.4.6.1 Transferability-Lab to Field

There are uncertainties involved in the transferability of information derived from short-term laboratory-scale (simplified) experiments to natural systems.

It is not clear what kind of field tests are planned or are actually being carried out. The only field tests discussed involved tests in granite. It is not clear how these results relate to basalt.

6.4.6.2 Natural Analogs

The discussion of natural analogs draws no direct relationship to the conditions at the RHO. In addition, because of ICRP revisions of the relative toxicity of radionuclide, DOE calculations that HLW is less toxic than a uranium or body, is no longer valid. Because of these revisions the relative toxicity of an ore body is now calculated to be lower while HLW is calculated to be substantially more hazardous.

RHO gives no specific plans for research on metal artifacts and nickel-iron meteorites and no discussion is provided to demonstrate how the environments of these analogs related to BWIP conditions.

6.4.7 Diffusion

TO BE ADDED

6.5 Recommendations to Close-Out Major Open Items

6.5.1 Major Open Items

The RHO plan for issue resolution involves bounding both near-field and far-field conditions and processes. Single-phase experiments involving waste/water/rock interactions under the anticipated environmental condtions are under way. Basic radionuclide solubility data are being integrated into the sorption experiment program. The sorption experiments are conducted using basalt, bentonite (possible backfill material) and typical basalt fracture-filling material. The open items involved with coming to closure on this work shall require studies and experiments to bound Eh, pH, radionuclide solubility, and sorption under anticipated repository temperature conditions.

6.5.2 Recommendations

6.5.2.1 Redox

Current EH field measurement techniques maybe inadequate for repository investigations because the sensing electrode may respond perferably to cetain aqueous species and not provide a representative measurement. Therefore, in addition to electrode measurement of Eh RHO effort to define ion couples is well targeted. However, to close out this item, Eh calculations have to be corroborated by petrographic observations and further experiments on the rate of oxygen comsuption by basalt must be run. Also, work has to be done to characterize the site-specific Eh envirnonment and to run experiments under site-specific Eh conditions.

The mechanism suggested by RHO for Eh control involves the coupling of groundwater and basalt, silicate and oxide phases presupposes diffusional processes. The same can be said for the RHO pH buffering mechanisms. Information on diffusion in the basalt is needed to substantiate diffusion.

6.5.2.2 Solubility

To close out this issue, is a need to greatly increase the collection effort of radionuclide solubility date (especially within the actinide series) on site-specific species. Also, solubility data are crucial to establishing reproducible sorption data. Further, it is possible that the low solubility of some radionuclide species may significantly limit radionuclide mobility and potential dose to man. For example, if the solubility limit of a radionuclide species is such that transport of the species would be below the EPA radionuclide release limit, than no additional retardation mechanism would need to be present and, alternatively, the presence of "sorption" would be a conservatism. The NRC believes that high temperature solubilities (steady-state condition) should be approached from both over- and under-undersation directions.

6.5.2.3 Sorption

To close out this issue, many engineered system parameters and components must be defined. These include waste form and load, use of an overpack, and backfill components. Only after these are considered can the form of radionuclides which might be released from the waste, the thermal and radiation pulse, and the expected radionuclide retardation be quantified. Additional experiments under expected repository conditions will be necessary to define radionuclide retardation in the near-field and far-field.

The use of sorption data for characterizing geochemical retardation arguements relies on demonstrated accuracy and reproducibility of the data. As the chemistry of radionuclide retardation becomes better understood, the complexity of the experiments increases. Given the requirement for data of high quality, there is a need for interlaboratory comparisons of research results in order to demonstrate reproducibility. In addition, results should be widely circulated in order to increase peer review.

Also, the NRC considers that in determining sorption behavior:

(a) Isotherms should be the minimum acceptable approach for quantitative analyses,

(b) Constant Kd's are only acceptable if the isotherm determination shows that the isotherm is linear,

(c) Materials for sorption determination should include altered basalt, fracture filling minerals, interbed materials, and fresh basalt, and

(d) The importance of colloidal transport should be addressed.

6.5.2.4 Temperature

In general, increased emphasis should be given to performing experiments over a range of temperature that bound those which will occur over the long-term in a repository. To date, insufficient attention has been given to the effects of temperature on geochemical processes. Most testing has been done under ambient conditions. The goechemical behavior of a waste-package, backfill, groundwater and surrounding host rock may alter significantly as temperature rises in the repository.

6.5.2.5 Analogues

Greater emphasis should be placed on understanding the causes and effects of naturally occuring processes that are relevant to assessing long-term repository and waste package performance. There is little evidence that knowledge gained from studies of natural analogues of repository systems of components has been utilized by workers in the laboratories, in the field or in modeling. There are uncertainties involved in the transferability of information derived from the study of ancient or existing natural occurences to the assessment of future geochemical changes in a repository. An understanding of natural analogues is needed to extrapolate in time and in space, the data and concepts derived from short-term lab-scale simplified experiments and modeling exercise, with greater confidence than we could have otherwise.

Emphasis should be given to forming a connection between the natural occurances of radionuclide migration being studied (natural analogues), site specific repository conditions and laboratory experiments. This connection is necessary in order to establish a basis for extrapolating with confidence the results of laboratory analyses and short-term field experiments to the assessment of the performance of a repository over long time periods. Further, such a connection would ensure that mathematical modeling is more than a paper exercise.

6.5.2.6 Performance Assessment Modeling

Communication among researchers and performance assessment modelers concerning the establishment of what is necessary, numerical performance assessment models, needs to be increased. For example, geochemists no longer give credit to Kd values although modelers continue to use these data. It is clear from the geochemical research performed thus far, that indiscriminant use of an empirical "Kd" (without taking into account a solubility and/or speciation function along with the serveral important and site specific parameters which control the extent to which these functions vary, viz: pH, Eh and temperature, etc.) will lead to unrealistic and unsupportable assessments. In addition, it is important for geochemists and modelers to determine through preliminary performance assessment the levels of precision and accuracy that can be tolerated in individual geochemical parameters. The development of this consensus will help focus the geochemistry research program. Finally, performance assessment models should better reflect the significance of the uncertainties inherent in the determination of geochemical retardation. Coordination between these groups is essential to prioritize and the fully utilize the data.

7 REPOSITORY CONCEPTUAL DESIGN

Repository design issues are identified by DOE in Chapter 14 of the SCR. Most of the design issues identified by the BWIP compare favorably with the issues independently identified by the staff (see Appendix C). The DOE issues generally cover the following: 1) Stability and isolation capability of the repository (DOE Issue R.1.A); 2) Rock mass strength (R.1.B); 3) In situ stress (R.1.C); and 4) Shaft, tunnel and borehole construction and sealing (R.1.D).

The staff notes that there is some overlap with waste package and performance assessment issues (e.g., what is the maximum expected release rate from the engineered system). Depending on hydrogeologic and geochemical tests, or estimates of these parameters, design of the backfill and emplacement configuration has an impact on the release rate.

One of the deficiencies of the SCR is that it does not identify retrieval as an issue to be considered during the conceptual design stage. The rest of the 10 CFR 60 performance objectives (i.e., travel time, containment time and release rates) are identified explicitly. The retrieval performance objective needs to be treated as an issue to be addressed during site characterization.

Another deficiency is that the SCR does not address "provisions to control any adverse, safety-related effects from site characterization, including appropriate quality assurance programs" (10 CFR 60.11(b)(iii)) as required in the procedural rule. As a minimum, the SCR should discuss in detail or reference provisions to control any adverse effects from construction of the exploratory shaft. Quality assurance aspects associated with the construction and sealing of the exploratory shaft should also be addressed.

The staff's overall impression of the plans presented in Chapters 14 and 17 is that the logic relating identified issues with proposed plans has not been clearly
expressed. This deficiency makes it difficult if not impossible to decide on the adequacy of the proposed testing programs, because data requirements and

their use in the design have not been outlined. While the staff realizes the need to keep the test plans flexible to respond to actual test data, it is necessary to define in as much detail as possible the current proposed test plans with proper references to existing DOE documents. The staff notes that the SCR does not reference "Supporting Document Test Plan For Exploratory Shaft Test Facility - I In Basalt" RSD-BWI TP-007 dated August 1981, as an example.

Based on the staff's review of the SCR, the following areas are identified as major concerns with the material presented in the SCR: (1) Stable Openings/ Conceptual Design; (2) Engineered Barriers; (3) Sealing; and (4) Retrievability.

These topics are discussed in detail below.

7.1 Stable Openings

The design of stable openings is an integral part of the repository design because it affects the integrity of canisters in waste emplacement holes, the ability to retrieve waste, operational safety, and the long-term performance of the engineered barrier system. Thus, the logic for the repository design and that of the stable openings should be closely related to the overall performance of the total repository system.

The conceptual design contained in the SCR and subsequent design updates must be based on technically sound criteria and tested predictive models. The results of such a design process will then indicate the nature and content of the test plans required prior to a License Application. In the opinion of the staff, the design process and the logic behind the design assumptions are not clearly stated in the SCR, and thus the staff has insufficient information to evaluate the adequacy of the conceptual design and the associated test plan. Further, the staff notes that conclusions drawn on optimization of the conceptual design including statements of extraction ratios, pitch of horizontal emplacement holes and method of waste emplacement should be considered tentative.

The above observation is based on the information presented in the SCR related to the assumptions and partially verified test data on controlling critical parameters and inadequate models to describe and predict fractured rock mass behavior. As an example, 200 MPa rock strength, 300°C limiting temperature, assumed elastic behavior for the thermal and mechanical response of jointed rock mass, and assumptions of in situ stress ratios and magnitudes are at best only approximate estimates. Even at this conceptual design phase, the disturbed zone and accompanying stress distribution around underground openings must be recognized, so that the sensitivity of the opening to the stresses present can be realized and its effects on basic design concepts assessed.

The staff is concerned that the design process and associated test plans (See Appendix Y) related to stable openings as presented in the SCR have not taken into account geologic and hydrologic variability. Specific attention to incorporating these concerns should be provided in future SCR updates. Specifically, the updates should pay attention to the following:

- The overall design logic should relate the design of openings to the overall performance of the repository with due consideration to the design of engineered barriers and provisions for the retrievability option. The relationship between in situ stress and excavation and thermally induced stresses to the rock mass strength should be defined. In addition, the deformation of the openings particularly the waste emplacement holes, during the retrievability period should be estimated using appropriate test data and models.

- The in situ stress data should be carefully analyzed to provide the design criteria and assumptions for design optimzation. Evidence provided by core discing should be taken into account in estimating the in situ stress conditions. Problems associated with the hydrofracturing technique and the limitations of the procedure and the resulting data should be identified. For example, the difficulty in interpreting test data when the vertical stress is the minimum principal stress.

- o Design analyses should reflect the discontinuties in the rock mass and state-of-the-art analytical approaches should be used in analyzing the coupled thermomechanical and hydrological behavior of rock mass (See Appendix O).

The SCR identifies that the design approach and the associated test plans are flexible and may be changed with the availability of new information. In view of the above, the staff opinion is that the logic of the design process including the proposed decision analysis techniques should be clearly stated in future updates in conjunction with any changes, the reasons for changes and verification of the critical input parameters, with descriptions of predictive techniques used in the process. Such an approach will provide an essential framework for supporting the design of the repository at the time of License Application.

7.2 Engineered Barriers

Engineered barriers are a part of the engineered system and thus affect the performance of the repository. The degree to which the engineered barriers will affect the repository system can be measured by comparing the predicted release rates with the (proposed 10 CFR 60) 10^{-5} release rate from the engineered system, and the overall system criteria established by EPA at the accessible environment. As further data and understanding is aquired, this comparison will indicate the importance that should be placed during the Site Characterization Process on engineered barriers. Further, this comparison will provide guidance concerning the required specification of the components of the engineered barriers.

Due to current single point assumptions of hydrologic properties and predictive thermo-geohydrologic models, the SCR suggests that apart from the waste package itself, engineered barriers will not materially affect the performance of the repository system. However, changes in hydrologic parameters and assumptions in emplacement configurations will demonstrate that engineered barriers other than the waste package could be significantly more important in controlling release rates than currently stated in the SCR.

The conceptual design considers waste emplacement in horizontally bored holes. The current assumption and estimates of the hydrogeological and geochemical framework and the waste heat load dictate an essentially vertical groundwater flow path through the potential repository horizon. These considerations dictate that the potential release rates of almost all radionuclides from the edge of the emplacement hole is essentially the same as release rates calculated at the boundary of the waste canister itself except for relatively minor delays in commencement time due to the presence of a few inches of backfill in the annulus. These opinions are borne out in several studies including those summarized in Appendix W. Thus, it would appear that the contribution of engineered backfill in controlling release rates in the current BWIP conceptual design is small. The release rates decrease in an approximately exponential sense as the path length of an engineered barrier with favorable retardation characteristics increases. Therefore, it is the opinion of the staff that engineered barriers could become vital contributors to controlling release rates. Future testing and analyses may dictate a change in the current hydrogeological, geochemical, and associated modeling assumptions. In such an event the requirements of engineered barrier design may read to a change in the emplacement hole configuration. Further, such a change in design may dictate alterations of in situ and other test plans during site characterization to adequately determine the properties and verify predicted performance of engineered barriers.

The design of the alternative engineered barriers and their predicted performance should be assessed as they contribute to controlling release rates of the engineered system and thus to the performance of the entire repository system. Thus, the logic of how the site issues relate to engineered barriers should be presented in future updates to the SCR.

7.3 Sealing of Boreholes, Shafts, and Underground Openings

The man-made openings required for characterization and access to the high-level waste repository in basalt must be sealed at permanent closure of the facility (proposed 10 CFR Part 60; § 60.2). The regulatory requirements of the proposed rule, provide criteria on the performance of these seals (proposed

10 CFR Part 60; § 60.134) and the information that is needed to assess this performance (proposed 10 CFR Part 60; § 60.142).

Chapter 10 and 14 of the SCR describe current efforts to establish performance requirements and design criteria for a seal system (key issue R.1.D). The SCR correctly notes the need for identification of performance requirements for sealing (work element R.1.18) as a priority item. Initial efforts, therefore, have been concentrated on computer modeling (RAFSCATT program) to define an acceptable flow rate and travel time for the seal system and other isolation components. The staff offers opinion that a reasonable range of values should be used to assess the performance objectives. Further, the staff is concerned with the schedule for development of seal materials. Figure 17-9 in the SCR shows that selection of candidate materials does not start until 1984. This seems late. This is a controlling factor in accomplishing the other work elements. Until the selection process is complete, other work such as placement methods, testing and verification plans, quality assurance procedures, equipment to be used, etc. cannot be determined.

The staff is also concerned that DOE arbitrarily included all sealing (sealing of boreholes, shafts, tunnels and liners) together. While materials used to seal boreholes, shafts and tunnels may be similar, placement techniques, verification methods and environmental conditions will most likely be quite different. These will cause differences in how the seals are designed and tested. Table 14-2 lists 10 work elements designed to resolve the key issues of sealing. Although many of the major concerns of sealing are listed, there is no logical approach presented on how this information will be collected or how it will be used to design a sealing system. The only specific reference to testing is in Chapter 17 under test program objective 3 to be carried out in the exploratory test shaft. This test will measure only depth of disturbed rock, water inflow, pressure differential, and grout strength. However, there are many other concerns that remain unaddressed; such as long-term stability of seals, placement and testing techniques to be used, etc., (See SIA 4.5.1 and 4.5.2).

Sealing studies by D' Appolonia (1978, 1980a, 1980b) and Taylor (1980) have identified a number of areas that require further investigation for seal design. One of the most important of these is long-term stability of seals. Because performance of the seal system must be adequate over a time span exceeding any reasonable test period, short-term test results must be extrapolated to the long-term using analytical methods. This extrapolation must cover the chemical and mechanical stability of the seals under a range of temperatures, the bond strengths to rock considering the presence of drilling mud and joint filling, and many other parameters. Long-term or accelerated laboratory and field testing must serve as the basis for this extrapolation. The SCR does not describe how this testing will be done or how the extrapolation will be made.

Another area lacking knowledge is the extent of damage of the wall rock surrounding an excavated opening induced by the excavation process or the redistribution of stresses. Although the SCR outlines testing to evaluate this disturbed zone in the exploratory test shaft, there are no plans provided to study the scale effects of the disturbed zone for different sized openings (boreholes to 19-foot diameter shafts) or the effects of different excavation schemes (i.e., conventional sinking with freezing vs. blind boring).

Other areas not addressed in the SCR are reliability of sealing techniques and quality acceptance criteria to be used in determining seal effectiveness. All of these concerns should be addressed early in the program to insure reliable seal design prior to license application.

7.4 Retrievability

Retrievability must be a planned contingency incorporated into the repository system but need not be specifically designed in as an end item. Rather, any repository systems must not preclude retrieval as required and defined by 10 CFR 60, 132(4)(d). Hence, retrievability will affect design, operational, and safety considerations. The staff is of the opinion that events or situations leading to retrieval should be described in sufficient detail to assess the adequacy of retrieval as a planned contingency. Retrieval may be full or total retrieval of the entire inventory or local retrieval of one or more canisters for some reason (Appendix X). Such retrieval alternatives need definition.

The staff is concerned that the SCR is vague concerning the impact of retrievability on repository design. Specific provisions of design resulting from retrieval are not clearly indicated. For example, the six-inch annulus around canisters in the emplacement hole is indicated as aiding cooling of canisters, when, clearly backfilling and retrieval are aided as well. If cooling were no longer required, would the benifits to backfilling and retrieval be compromised by minimizing the annulus size?

The staff notes that the rate at which canistered wastes are planned to be emplaced is one of the major factors determining the total effective shaft diameters (Appendix X). This decision, which must be made early in the conceptual design phase, will affect many of the repository operations and, particularly, once fixed, will control the rate of emplacment and retrieval.

The retrieval at any time in repository operations of one or more canisters, but less than the total inventory of canistered wastes (local retrieval, defined in Appendix X), is not considered in the SCR. This scenario of local retrieval does not consider local hydrologic or geologic factors and possible accidents under which individual canisters could be breached.

The staff is of the opinion that the effect of local retrieval on fixed ventilation capabilities should be integrated into the design process. These retrieval scenarios should include but not be limited to cooling the emplacement rooms and treating contaminated air during different stages of repository development. These assessments are required to establish the allowable rate of retrieval, and the safety requirements for the operating personnel.

The rate of groundwater flow into the repository is as yet undertermined. No scenario is offered in the SCR that considers the effect of groundwater contamination due to a breached canister, nor to the procedures that will be used to detect and control this contaminated water within the repository before it is treated on the surface. Although monitoring for radionuclide releases in the canister waste rooms is mentioned, the threshold values which indicate a breach and the measurement techniques for both air and water borne contaminents are not presented.

The methods used for retrieving breached canisters from horizontal waste emplacement holes assumes that the procedure is a simple reversal of the emplacment procedure. Such retrieval procedures will need to be presented at License Application, incorporating anticipated environmental conditions at the time of potential retrieval. The effect of locally retrieving breached canisters on air quality, operating personnel, groundwater if present, and removal of contaminated materials or equipment must be considered.

Consideration is given to a plan for backfilling the waste emplacement rooms after about five years while still maintaining the retrieval option. The staff notes that such action, if undertaken, will implicitly assume that no scenarios during the subsequent operational and decommissioning phases of the repository will be encountered which will exceed the design and performance limitations imposed during the initial five year verification period. Cooling and removal (remining) of backfill is mentioned as a pre-requisite to retrieval under these conditions, but this clearly time-consuming and difficult task needs careful development and full consideration of the impacts from backfill (environmental as well as radiological) conditions. The staff's overall impression is that DOE should adequately consider and develop the impact of these anticipated conditions on equipment performance, personnel safety, and potential radionuclide release into the ventilation and water circuits while cooling, remining, and retrieving. Then, remining of backfill may be maintained as a viable scenario to be incorporated into repository design and operation.

8 WASTE FORM/WASTE PACKAGE MOCKUP

8.1 General Waste Package Performance

This will be an introduction to the BWIP Waste Package design and its functions as a barrier component.

The reference BWIP waste package design (see Appendix A for an illustration of this design) includes three major potential barriers which can contribute to isolation of radioisotopes from the biosphere. They are the crushed basalt/bentonite clay packing surrounding each carbon steel container, the carbon steel container, and the waste form. These waste package components act to first exclude water from the waste form, and second, to control release from the waste package to the underground facility. The packing and the container can be functional in the first case and all three components may act to a significant degree to control release once containment has been lost. Depending on the waste form (either borosilicate glass or spent fuel) release rates subsequent to container failure may vary significantly.

The purpose of this chapter is to identify the most significant technical issues needing resolution during site characterization to determine whether or not the performance of the waste packages, including their contribution to engineered system performance, is of sufficient reliability to justify a finding that there is reasonable assurance that the overall repository system will meet EPA standards. (See 10 CFR 60.113 for the pertinent performance objectives.) A description of an acceptable method for integrating waste package and engineered system performance into an overall repository system assessment is contained in Appendix D.

In addition, this chapter identifies issues needing resolution during site characterization to demonstrate whether or not the waste package design meets design requirements of 10 CFR 60.135 concerning the evaluation of various chemical, physical, and nuclear processes and demonstration that waste packages and the underground facility performance is not compromised by synergistic interactions.

Finally, this chapter assesses the adequacy of the BWIP Site Characterization Plan to resolve the major technical issues. Other waste package-related issues of lesser importance, along with respective Staff assessments, are identified in individual Site Issue Analyses (2.1 through 2.27) referenced in Appendix C.

The following sections describe in turn a method for accomplishing an acceptable reliability analysis for the waste package, and the major technical issues related to the performance elements 3, 4, and 5, (see description in Appendix C), Penetration of Water to Waste Form, Waste Form Degration, and Radionuclide Transport through the Waste Package respectively.

8.2 Reliability of Waste Package

A major feature of activities associated with complex new engineering projects is the systematic evaluation and quantification of uncertainties in predicted component or system performance. Such evaluation and quantification can be accomplished by a reliability analysis. Such reliability analyses serve to demonstrate and document the quality of engineering designs and are considered by the Staff to be a necessary part of the BWIP project design control measures within the project's quality assurance program. (See evaluation of the BWIP quality assurance program in Chapter 10.)

In addition to providing a measure of the quality of a design, reliability analyses are also used to identify the importance of specific uncertainties in the overall system performance. When used for this purpose they are called sensitivity analyses and serve to focus research and development testing and/or design analyses to improve understanding of processes, material properties, and condition and, hence guide redesign or provide greater assurance of meeting system design or performance goals.

An acceptable methodology for performing such sensitivity or reliability analyses is described in Reference 8, NUREG/CR-2350. The methodology described in NUREG/CR-2350 was used to produce the sensitivity analyses described in Appendix D. The staff considers this methodology equally applicable to sensitivity/reliability analyses for waste packages as well as the entire engineered system.

BWIP Plan Evaluation

The BWIP Site Characterization Report does not identify plans for reliability analyses of the waste packages. This represents a major shortcoming of the project. The staff considers that early identification of reliability design objectives for each of the components of the waste package, as well as other barrier components, is necessary in order to achieve a coherent system design effort, properly documented in accordance with common fquality assurance program requirements.

8.3 Processes Controlling Waste Package Performance

To accurately quantify the source term the behavior of the waste package over long periods of times must be estimated. In order to accomplish this, it is necessary to consider the non-likely failure/degradation processes for the package components since this will allow radionuclide containment times and radionuclide release rates to be determined. Below are described what are judged to be the most important processes affecting waste package performance.

8.3.1 Pitting Corrosion

Low carbon steel undergoes both uniform and localized corrosion in aqueous environments. From a review of corrosion mechanism's (Appendix P) it is clear that the formation of pits is the non-likely way in which steel containers will be breached by groundwater in a basalt repository. In the pitting process, many workers have shown that pits from in localized regions where the oxide scale on the mental is broken. Hydrolysis reactions occur and there is acidification inside the site. If the pH is sufficiently low the break in the oxide film is not repaired and a deep pit begins to form.

To quantify the pitting of low carbon steel for the BWIP effort, it is necessary to carry out very low term testing under simulated repository corrosion to ensure that the time to initiate pits is less than the testing time. Tests under more aggressive (accelerating) conditions may also be carried out to obtain pitting characteristics more quickly and the data acquired extrapolated to prototypic BWIP conditions. The more important parameters to measure include (a) the pit initiation time, (b) the pit density and size as a function of time, (c) the pit propagation rate, (d) the Eh/pH, dissolved oxygen, and chemistry of the groundwater between the low carbon steel container and packing material as a function of time, and (e) the effect of temperature and gamma irradiation on the properties in (a) through (d). It is especially important to determine pitting behavior in welded steel since the structure of the weld is very different from that for base metal.

8.3.2 Waste Form Matrix Degradation

In modeling rates of release of the various components of solid nuclear waste forms exposed to chemical degration in aqueoue media, a distinction exists between the process which controls the overall degradation rates and transport of material away from the waste form under conditions of short repository water residence times (high flow) on one hand and of long residence times (low flow) on the other. At high rates (or high dilutions) the degradation rates are largerly affected by the leaching kinetics of the solid given whichever aged condition it can be in water, where the composition of the water reflects the conditions prevailing in the environment of the waste package. At low flow rates the loss rates depend in part upon the thermodynamic solubility and upon the rate at which the water in contact with the solid (which has been considerably modified as a result of dissolution of species from the waste form) is replaced with fresh, unreacted water. Under repository conditions, water exchange rates are likely to be low in a large number of cases, and therefore solubilities constitutes a key factor in determining the long-term durability of the material.

As mentioned above, water subjected to prolonged interaction with the material becomes substantially altered. This alternation of the composition affects the reactivity of the medium with respect to the dissolution of a particular species from the waste form in the following ways: (i) pH changes, e.g., increase in pH due to dissolution of alkaline components from the solid, cause large effects on solubility limits as well as on leach rates; (ii) increasing concentration levels of species of interest may result in approaching saturation in the case of nearly insoluble species; (iii) increasing concentrations of other degradation products can affect subsequent dissolution of the species of interest due to secondary interactions; (iv) increasing solute concentrations in the aqueous phase can give rise to phenomona such as re-adsorption, ion-exchange and other modifications of the solid-liquid interface which affect further material transport processes across the surface (v) pH changes as discussed in (i) above may influence formation of complex ions for example, carbonate oxilate, sulfonate and ferro-silicate complexes, and colloidal particales which in turn pickup radionuclides and effect their mobilization (Macedo, Avgado). All of these processes affect transport of radionuclides in the engineered barrier system and hence rates at which they will be released from the system.

For an engineered system designed which does not include barriers which impide radionuclide transport or provide sorptive properties the release rate from the waste form would determine the engineered system performance. For engineered systems with multiple barriers controlling release the waste form release rates will greatly affect the reliability of the overall system performance.

Evaluation of BWIP Plan

Specific plans for collecting data to fully understand the processed described above are not presented in the BWIP SCR. Only a statement that such understanding will be obtained within the DOE waste package program.

Specific plans should multicomponent testing of materials utilized in the waste package with conditions controlled, i.e., gamma radiation, temperature and heat flux, must be accomplished to verify anticipated ranges of the key chemical parameters, Eh and pH, are properly identified as a function of water resident time. Testing to identify complexes and colloidal particles which occur in the multicomponent system must also be accomplished.

This will discuss most likely degradation processes in borosilicate glass.

8.3.3 Transport

For values of the hydraulic conductivity greater than about 10^{-11} cm/sec, the movement of water through the packing material in the presence of a hydraulic gradient may be described by Darcy's law for laminar flow through a porous medium. In this case the rate of transport of radionuclides depends on the mean velocity of the water and also on the sorption processes for particular radionuclide species in that medium. The sorption processes consist of mechanisms such as ion exchange and surface adsorption as well as precipitation of radionuclides within the packing material because of solubility limitations. Particulates carried by the flow of water through the packing material may also transport radionuclides. A thermal gradient across the packing material may superimpose convective motion of the water upon the Darcian flow with corresponding effects on the mean velocity of the water and thus on the transport of the radionuclides. In saturated packing materials with very low hydraulic conductivities ($<10^{-11}$ cm/sec) or in the absence of a hydraulic gradient, radionuclide transport through the material is dominated by diffusion processes. In addition to diffusion of radionuclides along a concentration gradient, thermally assisted diffusion across a temperature gradient is possible. See NUREG/CR-2755 (1982) and PNL-4382 (1982) for further details.

8.4 Material Properties and Their Changes

Owing to the hydrothermal conditions which will eventually provide in the repository after closure, significant changes will occur in the physical, chemical and mechanical condition of the waste package components. Short term laboratory tests will be inadequate to characterize the performance of the waste package since many of the changes will only become significant after very extended time frames. Quantification of the changes and their impact on waste package behavior need to be determined to reduce uncertainties in estimating radionuclide containment times, and radionuclide release rates, once containment has been lost. Below are discussed materials property changes which are judged to be of great importance with respect to waste package reliability.

8.4.1 Packing

The hydraulic conductivity, diffusion coefficients, and radionuclide retardation factors are the transport properties of the packing material which most directly affect the transport processes discussed in 8.2.3, above. These transport properties may change because of chemical degradation of the packing material by mechanisms such as loss of hydrothermal stability, aging, decrease in sorptive capacity by chemical reaction or poisoning, selective dissolution or leaching of the packing material matrix, and radiation effects including radiolysis, all resulting from near-field environmental conditions. The hydrothermal stability of the material is the principal source of uncertainty, depending not only on the temperature, but also on the groundwater composition (including Eh and pH), the exchangeable cations within the material, the extent of water saturation, and pressure. The transport properties of the packing material may also change as a result of the self-sealing properties (swelling pressure and plasticity) of the bentonite component upon the sorption of water; the accompanying increase in the compaction density may cause a decrease in the hydraulic conductivity. (BNL-NUREG-31770, 1982)

8.4.2 Waste Forms

(Add Section by Cook)

8.4.3 Containers

The integrity of the container is central to the predictions of the radionuclide containment time and subsequent radionuclide release. Physical changes in the container, for example, the size and distribution of pits and the pressure of voluminous oxide scale will be expected to control the water flow rate over the surface of the waste form and, therefore, affect the leach rate. In order to reduce uncertainties regarding the rate of water flow passed the waste form surface estimates need to be made of the water penetration rates through the oxide layers on the container surface and through pits which are filled with corrosion products. If accurate water flow rates can be determined, it will significantly improve the estimation of waste form leach rates and radionuclide release rates from the engineered system and to the accessible environment.

8.5 Condition Affecting Waste Package Processes

The conditions which affect processes involving waste package performance can be divided into four major categories: (1) chemical, (2) thermal, (3) hydraulic and (4) mechanical. Chemical conditions are generally the most difficult to determine owing to the complicated set of reactions involving hundreds of different chemical species in the repository environment. In general, only bounds on key chemical parameters can be predicted with confidence. Hydraulic and mechanical conditions are more accurately predictable because good modeling is available. Also, pertinent material properties can be readily measured to facilitate the prediction of mechanical and hydraulic conditions with time. The best understood are thermal conditions although uncertainty in hydraulic conditions can reduce this understanding.

It is this staff's conclusion that knowledge of conditions over the life of the repository is most limiting in demonstrating high reliability in system performance. Uncertainties in the quantitative modeling of processes and determination of pertinent material processes--area discussed in the sections above--are of lesser importance in the reliability analyses.

Discussion of major issues related to chemical and mechanical conditions follow.

8.5.1 Chemical Conditions

During the first several hundred years after waste emplacement, the immediate surroundings of the waste package may change from a high temperature, high radiation, acidic, oxidizing environment to a cooler, alkaline, reducing one. These changes in physicochemical conditions will affect the corrosion resistance of the container, the degradation of the waste form and the generation of species for transport.

At present, it is not possible to predict the solubilities of radionuclides at elevated temperatures (150-300°C) with confidence. Most of the available radionuclide complexation stability constants have been obtained at temperatures below 50°C. Theoretical calculations and a limited amount of experimental data at elevated temperatures suggest that some of the actinides and rare earths in candidate waste forms exhibit negative temperature coefficients of solubility.

Waste elements which can have several oxidation states may exhibit lower solubilities under reducing conditions. The solubilities of monovalent elements generally will be independent of redox potential, unless the element forms complexes with liquids whose concentrations are Eh-dependent. The solubilities of elements which form aqueous hydroxyl or carbonate complexes and solid oxides, hydroxides and carbonates may exhibit a complicated dependence upon the pH and alkalinity of the solution.

The leaching behavior of waste glass and spent fuel is also dependent upon the environmental conditions described above. Degradation rates of the waste form generally increase with temperature and can be related to the Arrhenius equations. The relationship between temperature and leach rate of an individual radionuclide is element-specific and depends upon the solution chemistry, the formation of secondary phases and the thermal and radiation history of the waste form. Studies of the leach behavior of borosilicate glass in the presence of packing material, basalt and canister material suggest that synergistic effects in the waste package system could be as important as effects observed in simpler waste form-water systems. A non-trivial fraction of the radionuclides could be released from the waste pakcage as radiocolloids or pseudocolloids. Radionuclides can be sorbed by or complexed with ferrosilicate and aluminosilicate colloids and complexes produced by degradation of the canister and glass matrix. The radionuclide species produced by degradation of the waste form and the rates of radionuclide release from the waste package are very dependent upon intensive physicochemical parameters of the system and as well as interactions between the system components.

8.5.2 Mechanical Conditions

There does not appear to be a detailed evaluation in the SCR of the anticipated stresses that will act on the BWIP container/packing material system. Stresses arising from seismic and lithostatic/hydrostatic effects, and bentonite swelling pressures must be addressed in detail if uncertainties in the deformation of the container are to be assessed. In the SCR (Vol. II, p. 6.2-5) it states that the estimated lithostatic stress in the Umtanum layer, based on rock overburden stresses, is about 11.1 MPa. However, work reported by ONWI (1980) shows that in Stripa granite the horizontal component of the stress could be close to double the value calculated from rock overburden considerations. It is, therefore, necessary for similar in situ stresses to be measured at depth to determine the maximum anticipated stresses which could act on the BWIP container/packing material system.

Swelling pressures in bentonite need to be evaluated under prototypic test conditions since values as high as 20-30 MPa have been measured in the laboratory (PNL-3873, 1981). An additional concern requiring investigation is the possibility that the swelling pressure is additive to the hydrostatic pressure (AESD-TME-3113, 1981). If this is the case then the design stress for the container may be exceeded.

Finally, there is considerable uncertainty regarding the magnitude of stresses from rock movements, and their impact on container failure. For granite, Pusch (1977) stated downstream stresses could be exerted on container/bentonite/quartz sand systems due to rock movement along fault planes in granite. Containers lying across the fault plane could fail if they were not designed to read the maximum shear loads. The packing material according to Pusch, could help alleviate the problem by acting as a deformable medium adjacent to the container. A detailed stress analysis is, therefore, necessary to determine if the BWIP container will remain intact during rock movement along a plane intersecting the container.

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9 SITE CHARACTERIZATION ANALYSIS: INSTITUTIONAL AND ENVIRONMENTAL FACTORS

9.1 Introduction

In this chapter of the Site Characterization Analysis, the staff will point out the environmental factors at Hanford that could be particularly sensitive to the operation and construction of a geologic repository. Environmental factors will be used as a collective term for institutional, ecological, and radiological factors and air and water quality.

NRC regulation 10 CFR 51 requires DOE to prepare an environmental report as part of a license application for constructing a geologic repository. The NRC, in turn, will prepare an environmental impact statement (EIS) for its decision to authorize the construction of a repository. In preparing the EIS, the staff will depend to a large degree, upon the DOE environmental report for pertinent and reliable data.

The BWIP Site Characterization Report (SCR) describes, in general, the type of environmental data that will be presented in the environmental report. The staff feels that the DOE has overlooked a few environmental issues that, if left unresolved, could protract the NEPA process and delay licensing. In this review, the staff will identify these environmental issues and recommend how they should be resolved.

9.2 Institutional Factors

For the purposes of this review, the staff defines an institutional factor as an objective of an organized segment of society (e.g., state and local laws, Indian tribal views). Institutional factors are not discussed, in detail, in the SCR. DOE has held some public workshops and hearings. The staff expects that these public meetings will become more frequent as licensing approaches.

DOE has not adequately shown, however, the means used to obtain public, Indian tribal and State views during the selection of the reference repository location (see 10 CFR 60.11).

The staff recognizes that Hanford's prior long-standing use and commitment to nuclear activities and existing government ownership may preclude some institutional concerns during the site-selection process. Thus, institutional factors may not occur to the same degree at Hanford as they might at non-DOE land.

9.3 Ecology

The SCR identified three wildlife preserves within the Hanford Reservation: the Saddle Mountain National Wildlife Refuge, the McNary Wildlife Refuge, and the Arid Lands Ecology Reserve (managed by DOE). It appears, from Figure 9-1 in the SCR, that the reference repository location would not extend into any of the wildlife preserves. The SCR does not mention, however, that both the reference repository location and its alternate lie completely within the Rattlesnake Hills Critical Wildlife Habitat (CWH) and 25% of each lies within the Cold Creek Critical Wildlife Habitat (Ref. 1).

Although DOE may be able to construct a repository at the reference repository location without diminishing its ecological value, the DOE should recognize the location's ecological significance. Provisions of the Endangered Species Act regarding critical habitats and endangered species should be considered before DOE commits itself to the reference repository location (RRL). The SCR states: "Two threatened and endangered bird species, the bald eagle, Haliaeetus leucocephalus, and the peregrine falcon, Falco peregrinis are known to occur as winter migrants on the Hanford Site." The SCR does not recognize the status of some other important bird species which nest at the Hanford Site. The prairie falcon (Falco mexicanus) nests in several regions on the Hanford Site, with the number of nesting pairs being approximately six. This species is listed as threatened by the U. S. Department of Interior (Ref. 2). The western burrowing owl and the long-billed curlew (both possibly in danger) nest on or near the reference repository location in significant numbers, particularly around the 200 area (Ref. 2). DOE should keep abreast of the status of all rare, endangered, threatened or special species that could be affected by the construction and operation of a geologic repository.

9.4 Water Use

Given the arid environment of the Pasco Basin, a repository could compete with irrigated agriculture for water. During a repository's construction, large quantities of water will be needed for drilling and dust control. Coupled with continued agriculatural growth, a repository could have an impact on the area's water resources.

The SCR does not estimate the quantity of water needed to construct, operate and decommission a repository. Nor does the SCR identify the source of water or have any programs in place (i.e., work elements) that would obtain water-use information. This apparant oversight of possible water-use conflicts is inconsistent with a previous DOE position which states:

> "The source and quantity of water required for use in repository processes will be established during conceptual design. Water consumption should then be evaluated with respect to the results of an economic geology study (water resources assessment) by the Basalt Waste Isolation Project, which will provide an analysis of historical trends in regional water use. Together, these studies should indicate whether or not a potential conflict on water use exists in the Hanford Site" (Ref. 3).

The staff recommends that DOE complete the water-use studies described above.

9.5 Radiological Background

A shallow depression within the RRL, called "U Pond," has received radioactive effluents since the beginning of the Manhattan Project in World War II (Ref. 2). Additionally, five ditches or ponds, all within the RRL, are used for the disposal of low-level radioactive wastes, certain industrial wastes, laboratory and sanitary wastes and discharge of water used for plant cooling (SCR p.

7.1-11). As a result of these discharges, soil and vegetation within the RRL have a higher concentration of radionuclides than the median concentration for the Hanford area. Of 21 soil samples taken within the RRL, 10 show radionuclide concentrations higher than the Hanford median. ^{90}Sr concentration in the RRL soil (Control Plot No. 2) is more than 1000 times that of the Hanford median. Bioaccumulation of ^{137}Cs and ^{90}Sr into RRL vegetation (Control Plot No.2) is up to 100 times the median concentration for the Hanford area (see Tables 9-6, 9-7, 9-8, 9-9 in SCR), and groundwater beneath the RRL shows H^3 levels from 30 to more than 3000 pCi/ml (Ref. 1).

Knowing that a repository may be constructed in a contaminated area raises some questions on how DOE plans to monitor the repository's performance. Background radiation levels will fluctuate with the continued use of the RRL as a low-level waste disposal site. Likewise, radioactivity in the surface water (including the Columbia River) can change from day to day; depending upon what is being discharged and sampling conditions.

Reference 1 (p. iv-27) has indicated that repository development will be supported by additional monitoring. Yet the SCR contains little information on the repository monitoring program. Although it may be premature to discuss in depth how DOE plans to monitor radiation releases from a repository, the staff feels that DOE should affirm, as soon as possible, that Hanford's background radiation will not interfere with repository monitoring. Thus, the staff believes that DOE should consider how it intends to monitor the radiological performance of a geologic repository at Hanford.

9.6 Staff Conclusion

After reviewing the environmental and institutional sections of the BWIP SCR, the staff comes to the following conclusions:

- Institutional factors played a minor role in the BWIP site-selection process. DOE should explain if Hanford's prior commitment to nuclear activities and federal ownership precluded the need for considering institutional factors.

- DOE should examine, in detail, the ecological significance of the reference repository location. A mitigation plan may be needed for possible adverse impacts on two critical wildlife habitats and several bird species.

- DOE should ensure that a repository's water requirement will not limit agricultural growth.

- DOE should begin to consider how it intends to monitor the radiological performance of a repository at Hanford.

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10 QUALITY ASSURANCE PROGRAM

As noted in the procedural rule the NRC identifies Quality Assurance (QA) as a key element of site characterization activities for nuclear waste repositories. An adequate QA program is necessary to assure confidence in the geologic and geotechnical data obtained during site characterization and to assure licensability of the BWIP site. The NRC has established QA regulatory requirements for nuclear waste repositories in proposed 10 CFR Part 60, Subpart G.

The Quality Assurance chapter in the SCR addresses the 18 criteria of 10 CFR 50 Appendix B, and the material presented appears to be relatively well developed. DOE makes a destinction between technical and administrative documents. The staff considers the destinction very important in developing a QA program for geotechnical investigations. The above fact identifies that DOE has made a special effort in establishing a QA program that addresses the investigative nature of repository site studies. However, there are some concerns that will need attention in the future. The major concerns deal with the implementation of the QA program on specific geotechnical areas. These will be discussed in the following narrative. Other minor QA comments on the administrative portion the QA program will be discussed in Chapter 12.

The Standard Format and Content Guide (Regulatory Guide 4.17) states that "QA methods should be presented in sufficient detail to allow NRC to make an independent evaluation of the precision, accuracy, reproducbility, analytic sensitivity, and limitation of data acquisition and analysis methods that was used during site exploration and will be used during site characterization." In many of the technical areas, such a detailed presentation was not given. For example, calculated solubility limits were discussed in the geochemistry chapter. However, a discussion of the limitations of the solubility estimations was not given in enough detail for the staff to adequately evaluate it. Also, Regulatory Guide 4.17 requested a description of the quality assurance program to be applied to each planned test and a discussion of the limitations and uncertainity in the data. None of the plans listed in Chapters 13 through 16 have a designated level of quality assurance to be applied or a discussion of the limitations and uncertainty involved. Other major concerns involving implementation of the QA program include the following:

1. Reference of Key BWIP QA Documents. Many documents are referred to in the discussion of the QA program (e.g. implementing functional-procedures manuals, BWIP procedures manual, Rockwell data package manual, Rockwell functional manual, etc.) that are not listed as a reference at the end of the chapter. In fact, no BWIP document is referenced at the end of the QA chapter. If the QA program described in Chapter 18 is being implemented properly, then all of these documents should be identified as references in the QA chapter. Those containing the technical test procedures to be used during site characterization activities should also be made available to the public.

2. QA Organization. Section 18 of the QA Chapter states "Implementation of the quality assurance program for the BWIP is the responsibility of the BWIP Director". This is not considered an acceptable situation for implementation of the QA program. Implementation of the QA program should be a function of a QA Director, not the BWIP Director.

3. Reliability Analyses in Design Control. Section 18.3 should address the methods to be used to quantitatively define the degree to which analytic methodologies are verified for application to any particular time in the repository history. In this regard, it is expected that methods for reliability analyses and requirements for establishing reliability design goals for components and systems be identified.

4. Identification and Control of Samples. Several comments made in other chapters of the SCR indicate Section 18.8 of the QA program has not or is not being implemented properly. Statements such as "Sample identification, preparation, and testing techniques contributed significantly to this

scatter" (Page 4.1-7, Section 4.1.3, Paragraph 1, Sentence 6) may indicate a lack of adequate QA control of samples. These type of statements should be clarified.

5. Test Plans for Major Test Program. Section 18.11 states that test plans are prepared for each major test program. However, few test plans are referenced in the SCR for any of the major test programs mentioned. For example, the discussion of the exploratory shaft in Chapter 17 does not mention or reference any test plan. Since this activity is being conducted in the very near future, a detailed quality assurance program (including a test plan) should be available for the exploratory shaft. Further, few of the planned individual tests listed in the SCR reference test plans.

11 PERFORMANCE ASSESSMENT

11.1 General

The SCR presents (Chapter 12) a discussion of the long-term repository performance issues identified by the DOE including groundwater flow paths and travel times, repository radionuclide release rates, and releases of radionuclides to the accessible environment. Chapter 12 describes the DOE's overall approach to long-term repository performance analysis consisting of identification of release modes followed by analyses of release consequences using numerical models. The characteristics of these predictive models are described including the general mathematical models used to describe natural processes, the specific numerical computer codes used to implement the mathematical models, and the general verification, validation and benchmarking procedures appropriate for such codes.

Chapter 12 also presents the results of a number of preliminary performance assessments conducted for the BWIP site. These performance assessments suggest that the groundwater travel time from a repository to the environment is likely to exceed 10,000 years, and indicate that releases of radionuclide to the environment are likely to be within anticipated regulatory constraints. This chapter states that "substantial interpolation and subjective judgment were required to prepare the model inputs," and therefore, refers to these analyses as "in the category of performance assessment precursors." Section 12.4.5 discusses the uncertainties in the results of these preliminary analyses, and identifies some of the major contributors to uncertainties in flow path and travel time estimator.

Chapter 13 describes the plans for future site investigations, including studies (e.g., investigations of structures) which will help to refine the "conceptual model" of groundwater flow needed for specific groundwater and radionuclide transport analyses.

Chapter 16 discusses plans for additional performance assessment work including development and documentation of models and codes, verification and validation of codes, and additional performance analyses.

11.2 Conclusions and Assertions in the SCR

The major assertion of Chapter 12 is that the groundwater travel time will substantially exceed the NRC's proposed minimum value, and that releases of radionuclides to the environment will be below likely regulatory constraints. As noted previously, this chapter recognizes that performance assessments to date are very preliminary and are based, in part, on subjective judgment rather than actual data.

Chapter 13 and 16 assert that the plans identified are appropriate to resolve all outstanding performance assessment issues regarding the suitability of the BWIP site for disposal of high-level wastes.

11.3 Discussion of Critical Issues

The RC staff does not consider the assertions of Chapter 12 regarding groundwater travel time and readionuclide release rates to be adequately supported for the following major reasons.

11.3.1 Lack of Data

As noted in Chapter 12 of the SCR, there is a lack of reliable data for such analyses. The subjective judgments used to produce the model input required for these analyses appears, in some cases, to be "non-conservative" when compared to the limited experimental data available. For example, on page 5.1-46 the SCR states that the only experimental data available indicate an effective porosity in the range of 10^{-2} was generally used. Since the groundwater travel time is proportional to the effective porosity, substituting the more conservative value of 10^{-4} could reduce the calculated groundwater travel times by about two orders of magnitude.

Other deficiencies in experimental data are discussed in Chapter 4, of the SCA including the critical vertical conductivity parameter. Until better data are obtained experimentally, the results of groundwater flow and radionuclide transport calculations will be considered by the NRC staff to be inconclusive and largely speculative.

11.3.2 Incomplete Conceptual Model

The SCR states (page 13.2-28) that "the Gable Mountain-Gable Butte structure is currently interpreted to have an effect on groundwater circulation within the Pasco Basin, especially in providing a possible avenue of interconnection between the unconfined and the upper confined aquifer." However, the effects of this structure have apparently not been incorporated into the numerical groundwater codes used for the analyses of Chapter 12. Similarly, the SCR states on page 12.4-12 that "the two-dimensional analysis was basically an instructive exercise and the results are considered non-conservative." The NRC staff agrees that groundwater flow in the Pasco Basin may be inherently three-dimensional. While the Rockwell analysis described in Section 12.4.1.2.1 is a step-in the right direction, it is apparent that additional development of the conceptual model is needed. Additional deficiencies in the current conceptual model of the BWIP region are discussed in Chapter 4 of this SCA and on page 12.4-52 of the SCR. Until the conceptual model has been fully developed, and the numerical codes adopted to the conceptual model, groundwater flow analyses will remain inconclusive.

11.3.3 Lack of Code Validation

The SCR gives no indication that the computer codes used for the analyses of Chapter 12 have been validated for use at the BWIP site. The NRC staff considers code validation specifically for the BWIP site to be a critical step in demonstrating compliance with regulatory requirements for groundwater travel time and radionuclide releases. While the codes described in Chapter 12 appear to generally represent the state-of-the-art, it remains to be determined whether the current state-of-the-art is an adequate representation of the physical processes occurring at the BWIP site.

11.3.4 Incomplete Scenario Set

The set of disruptive event scenarios listed on page 12.2-4 does not include future groundwater pumping which could substantially alter the hydraulic grandient at the BWIP site.

11.4 Evaluation of Site Characterization Plans

The plans presented in the SCR related to performance assessment are, in some cases, merely statements of goals rather than plans for achieving those goals. The "plans" for code validation are particularly deficient in this respect.

The plans for code validation are essentially summarized in a single sentence from page 16.3-3 which states: "Validation of the performance assessment codes will be performed on two-levels: (1) validation using data from laboratory experiments, and (2) validation with field data from the candidate siting area." There is no information in the SCR to indicate the types of experiments which are planned, the relevance of these experiments for code validation, or the areal extent over which field measurements will be taken. There is only a slight clue as to the time duration of the validation work (apparently no more than a few years for laboratory experiments and the period of site characterization for the field work). It is also unclear whether specific field experiments are planned for the purpose of code validation or whether field validation is essentially incidental to other data gathering work during site characterization.

The SCR does not appear to present a definite plan for achieving a technical consensus on the appropriateness and completeness of the conceptual model of groundwater flow in the vicinity of the BWIP site.

Page 13.3-38 of the SCR states that "an iterative process exists between data collection and numerical modeling to assure that sufficient data are available for confidence in the modeling results." This process is not described further, and the site characterization plans do not include provisions for taking advantage of this process. There is also no indication of a plan or process for using collected data to validate or modify models and codes (except for the brief validation statement discussed above). It appears that this iterative process may not be serving its purpose since Chapter 12 of the SCR describes codes with a dual-porosity analysis capability, but the SCR contains no plans for obtaining the dual-porosity required for such a code.

11.5 Recommendations

Thorough plans should be developed for code validation. The NRC staff considers validation to be a critical step in performance analyses which will have a major impact on the validity of those analyses.

An explicit plan (e.g., a peer review process) should be developed for achieving a technical consensus on the conceptual model of groundwater flow.

The iterative process between data collection and numerical modeling should be described in more detail, and plans for its use should be developed.