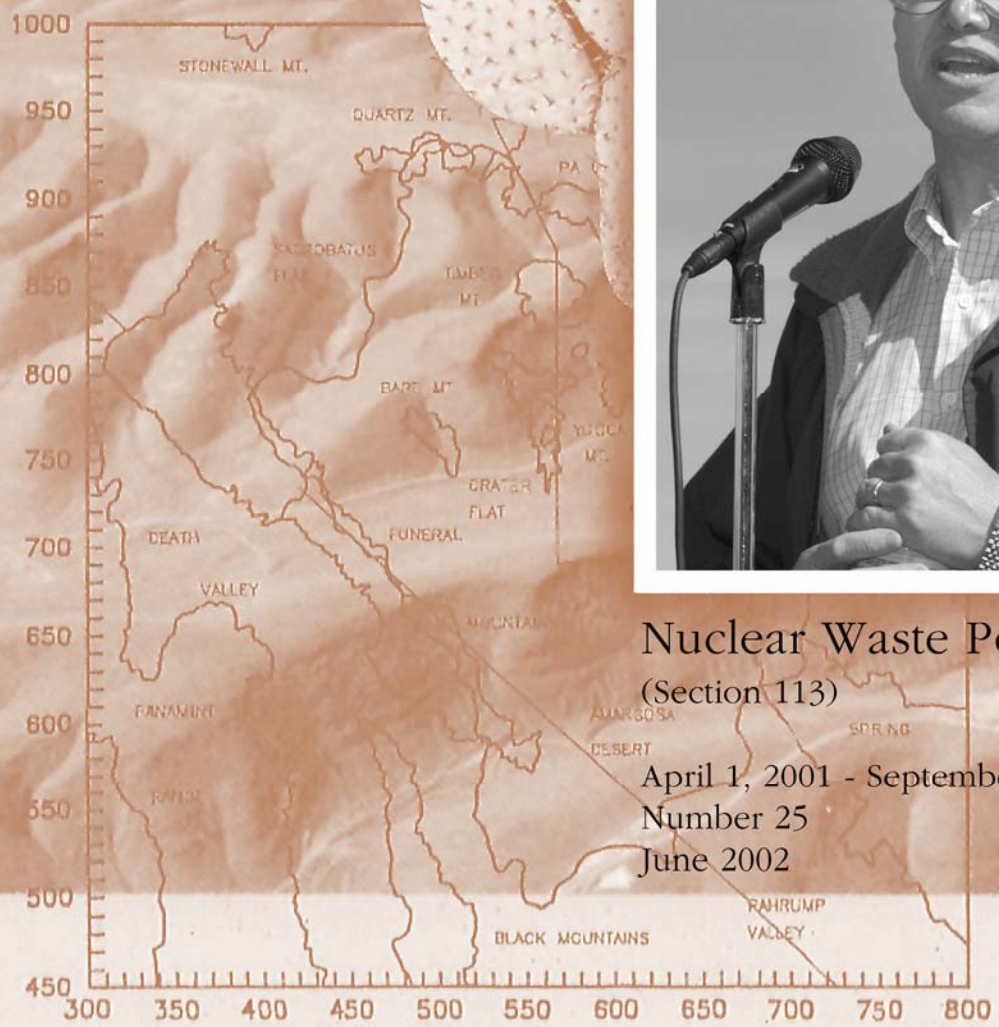
DOE/RW-0553

Site Characterization Progress Report

Yucca Mountain, Nevada



Nuclear Waste Policy Act

(Section 113)

April 1, 2001 - September 30, 2001

Number 25

June 2002

U.S. Department of Energy

Office of Civilian

Radioactive Waste Management

NOTE INSIDE FRONT COVER

The Nuclear Waste Policy Act of 1982 established the U.S. Department of Energy Office of Civilian Radioactive Waste Management. The Nuclear Waste Policy Act, as amended[1], directs the Office of Civilian Radioactive Waste Management to dispose of the nation's high-level radioactive waste and spent nuclear fuel in a geologic repository and prescribes other related activities. The NWPA requires a semiannual report on site characterization progress to be produced. Title 10 of the Code of Federal Regulations, Part 63 (10 CFR 63.16(b)), Disposal of High-Level Radioactive Wastes in a Geologic Repository at Yucca Mountain, Nevada, requires the report to:

- Describe the results of site characterization activities and information developed to date
- Describe waste form and WP research and development
- Identify new issues and plans to resolve these issues
- Discuss any planned studies eliminated because they are no longer necessary to site characterization
- Identify decision points reached and schedule modifications.

This is the 25th progress report issued by the U.S. Department of Energy. This report provides a summary-level discussion of the Yucca Mountain Site Characterization Project progress. Accomplishments this period are presented in a format that identifies important progress achieved and conveys how that progress supports the near-term objectives in the U.S. Department of Energy's schedule. Greater detail is documented in the cited references and in the deliverables listed in Appendixes A and B to this report. Readers may request any of these-approved Project documents by contacting the Office of Civilian Radioactive Waste Management Information Line at 1-800-225-6972.

This document provides a discussion of recently completed and ongoing activities conducted by the Yucca Mountain Site Characterization Project during the six-month reporting period from April 1, 2001, through September 30, 2001. Some information presented herein is, by necessity, preliminary because some deliverables and reports that support the information have not been finalized. Projected future deliverables and reports are listed in Appendix B and are noted in the text as works in progress. A glossary of Yucca Mountain Site Characterization Project-specific terms used in this report is given in Appendix C.

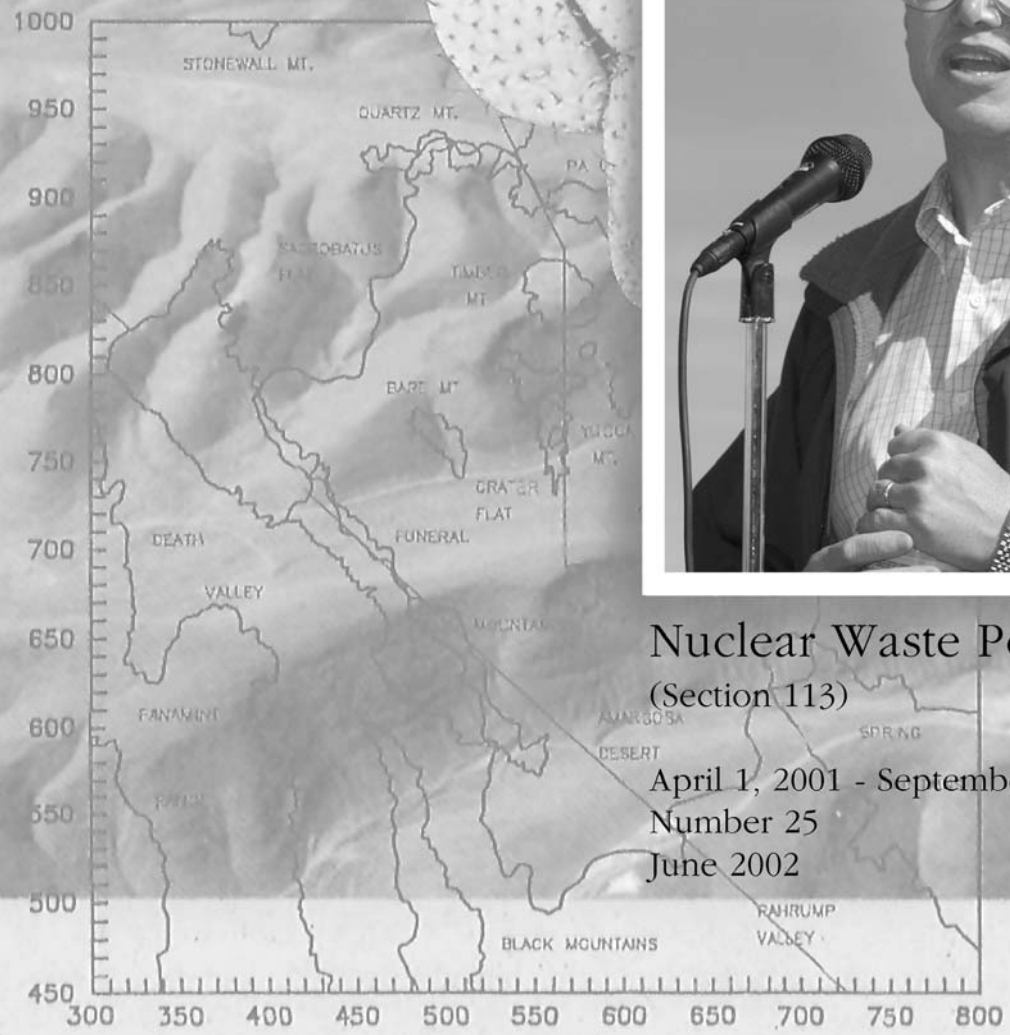
The *Documentation of Program Change*, last published in January 2001 as Revision 03, is being revised to Revision 04 (in progress) to update site characterization activities through September 30, 2001, in relation to the 1988 *Site Characterization Plan Yucca Mountain Site, Nevada Research and Development Area, Nevada*. Beginning with the reporting period of April 1997 through September 1997, the *Documentation of Program Change* was removed as an appendix to the semiannual progress report and published separately as reference material on the Yucca Mountain Site Characterization Project's site characterization program. The U.S. Department of Energy plans to revise this document annually.

[1] The Nuclear Waste Policy Act of 1982, as amended, consists of Public Law 97-425 (96 Stat. 2201) enacted on January 7, 1983. Subsequent amendments are Public Law 100-203 (December 22, 1987) and the Energy Policy Act of 1992, October 24, 1992 (Public Law 102-486). The Act is codified at 42 U.S.C. 10101 and following.

DOE/RW-0553

Site Characterization Progress Report

Yucca Mountain, Nevada



Nuclear Waste Policy Act

(Section 113)

April 1, 2001 - September 30, 2001

Number 25

June 2002

U.S. Department of Energy
Office of Civilian
Radioactive Waste Management

INTENTIONALLY LEFT BLANK

CONTENTS

Page

CONTENTS (continued)

Page

CONTENTS (continued)

Page

INTENTIONALLY LEFT BLANK

FIGURES

Page

INTENTIONALLY LEFT BLANK

ACRONYMS, ABBREVIATIONS, AND SYMBOLS

ACRONYMS AND ABBREVIATIONS

AMR	Analysis and Model Report
BDBE	Beyond Design Basis Events
BDCF	Biosphere Dose Conversion Factors
BSC	Bechtel SAIC Company
BWR	Boiling Water Reactor
cm	centimeter
DBE	Design Basis Event
DHLW	Defense High-Level Waste
DIRS	Document Input Reference System
DOE	U.S. Department of Energy
EBS	Engineered Barrier System
ECRB	Enhanced Characterization of the Repository Block
EIS	Environmental Impact Statement
EPA	U.S. Environmental Protection Agency
ESF	Exploratory Studies Facility
FEHM	Finite Element Heat and Mass
FEP	Features, Events, and Processes
FY	Fiscal Year
ft	feet
ft^2/day	square feet per day
ft/yr	feet per year
HLW	High-Level Radioactive Waste
HTGR	High-Temperature Gas-Cooled Reactor
ICN	Interim Change Notice
ICRP	International Commission on Radiological Protection
in.	inch
ISA	Integrated Safety Analysis
KTIs	Key Technical Issues of the NRC
LA	License Application
MGR	Monitored Geologic Repository
m^3	cubic meters
m^2/day	square meters per day
m/yr	meters per year
ml/hr	milliliters per hour
mm	millimeter
m	meter
mrem	millirems

ACRONYMS, ABBREVIATIONS, AND SYMBOLS (Continued)

NC-EWDP	Nye County Early Warning Drilling Program
NRC	U.S. Nuclear Regulatory Commission
NWPA	Nuclear Waste Policy Act of 1982
NWTRB	Nuclear Waste Technical Review Board
OCRWM	Office of Civilian Radioactive Waste Management
PMR	Process Model Report
PSA	Preclosure Safety Analysis
PSSE	Yucca Mountain Preliminary Site Suitability Evaluation
PTn	Paintbrush Tuff non-welded
PWR	Pressurized Water Reactor
QA	Quality Assurance
S&ER	Yucca Mountain Science and Engineering Report
SNF	Spent Nuclear Fuel
SSCs	Structures, Systems, and Components
SSPA	Supplemental Science and Performance Assessment
SR	Site Recommendation
SZ	Saturated Zone
TBM	Tunnel Boring Machine
TH	Thermal-Hydrological
THC	Thermal-Hydrological-Chemical
THM	Thermal-Hydrological-Mechanical
TM	Thermal-Mechanical
Tac	Calico Hills Formation
Tptpll	Topopah Spring Tuff, crystal poor lower lithophysal unit
Tptpv1	Topopah Spring Tuff, crystal poor vitric zone, nonwelded subzone
Tptpv2	Topopah Spring Tuff, crystal poor vitric zone, moderately welded subzone
TSPA	Total System Performance Assessment
TSw	Topopah Spring welded unit
USGS	U.S. Geological Survey
UZ	Unsaturated Zone
WP	Waste Package
W/m K	watts per meter Kelvin
YMP	Yucca Mountain Site Characterization Project
YMSCO	Yucca Mountain Site Characterization Office

SYMBOLS

Am	americium
As	arsenic
Br	bromine
°C	degrees Celsius

ACRONYMS, ABBREVIATIONS, AND SYMBOLS (Continued)

Ca	calcium
CaO	calcium oxide
Cl	chlorine
Cs	cesium
Co	cobalt
CO_2	carbon dioxide
H	hydrogen
H_2O	water
kg	kilogram
km	kilometer
Li	lithium
M	molar
Mn	Manganese
Na	sodium
Ni	nickel
nm	nanometer
Np	neptunium
O	oxygen
Pb	lead
Pu	plutonium
S	sulfur
Sb	antimony
Se	selenium
SiO_2	silica
SO_4	sulfate ion
Tc	technetium
U	uranium

INTENTIONALLY LEFT BLANK

SECTION 1 – EXECUTIVE SUMMARY

The 25th semiannual progress report of the Yucca Mountain Site Characterization Project (YMP) summarizes site characterization activities from April 1, 2001, through September 30, 2001. These activities are focused on evaluating the suitability of Yucca Mountain, Nevada, as a potential site for permanent geologic disposal of high-level radioactive wastes (HLW) and other nuclear materials, in accordance with the Nuclear Waste Policy Act of 1982, as amended (NWPA)[2].

This progress report documents the Project site characterization and other activities that contributed to completing the near-term programmatic and statutory objectives, which are:

- Developing the documentation needed to support a possible site recommendation (SR) decision by the Secretary of Energy on whether to recommend to the President the Yucca Mountain site for a geologic repository

- Completing the environmental impact statement (EIS) document for the Yucca Mountain site.

Major accomplishments during this reporting period are summarized briefly in this Executive Summary, and the detailed accomplishments are summarized in Sections 2 through 5. Section 2 summarizes the detailed progress on activities related to the near-term objectives, and Sections 3 through 5 present Project work on site characterization, design and construction, and repository performance, respectively. The Epilogue, Section 6, documents significant events that have occurred after the close of the reporting period. Section 7 provides a complete list of the cited references.

1.1 PROGRESS TOWARD NEAR-TERM OBJECTIVES

1.1.1 Site Recommendation

The following documents will be provided to the Secretary of Energy to support the potential SR decision:

- *Yucca Mountain Science and Engineering Report* (S&ER)

- *Final Environmental Impact Statement for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada* (Final EIS)

- Site suitability evaluation

- SR comment summary document that includes the views and comments of the Governor and legislature of any state, or the governing body of any affected Indian tribe

[2] The Nuclear Waste Policy Act of 1982, as amended, consists of Public Law 97-425 (96 Stat. 2201) enacted on January 7, 1983. Subsequent amendments are Public Law 100-203 (December 22, 1987) and the Energy Policy Act of 1992, October 24, 1992 (Public Law 102-486). The Act is codified at 42 U.S.C. 10101 and following.

- U.S. Nuclear Regulatory Commission (NRC) comments concerning the extent to which the at-depth site characterization analysis and waste form proposal seems to be sufficient for inclusion in any application to be submitted for licensing of a repository at Yucca Mountain

- Other documents, as deemed appropriate, such as the total system life cycle cost report and the fee adequacy report.

During this reporting period, several significant events occurred related to some of these documents and the site recommendation process. On May 7, 2001, the U.S. Department of Energy (DOE) announced initiation of a public comment period on the Secretary of Energy's consideration of the Yucca Mountain site for recommendation as a geologic repository (66 FR 23013). In conjunction with the announcement, the DOE issued the S&ER, which summarizes the scientific and technical information compiled to date regarding the preliminary design and performance attributes of a potential geologic repository at the Yucca Mountain site. Three other reports were released at this same time: a *Supplement to the Draft Environmental Impact Statement for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada*, an updated total system life cycle cost report, and an updated fee adequacy report. On August 21, 2001, the DOE announced the issuance of another report, the *Yucca Mountain Preliminary Site Suitability Evaluation* (PSSE). This report contains a preliminary evaluation of the suitability of the Yucca Mountain site for development as a geologic repository. The report is based on information contained in the S&ER, supplemented by the most recent available technical information, including evaluation of a range of thermal operating modes for the potential repository.

The intent to hold public hearings, and to have a public comment period on the Secretary of Energy's consideration of the Yucca Mountain site for possible recommendation to the President as a nuclear waste repository, was announced in a Federal Register notice dated May 7, 2001 (66 FR 23013). The specific dates for such meetings were established in subsequent Federal Register notices on August 21, 2001 (66 FR 43850), and September 27, 2001 (66 FR 49372). A public hearing was held in North Las Vegas on September 5, 2001, with videoconference connections to Reno, Carson City, and Elko, Nevada. A satellite link was also established with Washington, D.C., to allow the Nevada Congressional delegation to provide its views. Public hearings in Amargosa Valley and Pahrump, Nevada, were rescheduled for October 10 and October 12, 2001, respectively, in response to requests by the public and the September 11, 2001, terrorist attacks on the United States.

As of the end of this reporting period, approximately 3,678 comments have been received, in the form of letters, faxes, e-mails, and transcripts.

1.1.2 Environmental Impact Statement

The NWPA, Section 114(f)(1), requires that a Final EIS accompany any recommendation to the President by the Secretary of Energy.

The DOE issued the Supplement to the Draft EIS updating the information in the *Draft Environmental Impact Statement for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada*. The supplement evaluates potential environmental impacts that could occur, based on the current repository design and a range of possible operating modes.

The repository design has continued to evolve, reflecting evaluations of design options and operating modes that would reduce uncertainties and improve long-term performance, operational safety, and efficiency. Although aspects of the design have evolved, the basic elements of the proposed action to

construct, operate and monitor, and eventually close a geologic repository at Yucca Mountain remain unchanged from the design in the Draft EIS.

Public hearings on the Supplement to the Draft EIS were conducted in the state of Nevada in Amargosa Valley on May 31, 2001; in Las Vegas on June 5, 2001; and in Pahrump on June 7, 2001. DOE received 1,913 comments that will be considered as the Final EIS is prepared.

1.1.3 Regulatory Framework, Interactions, and Strategy

The Energy Policy Act of 1992 shifted from a generic to a site-specific regulatory framework for evaluation of and decision-making about a potential repository at Yucca Mountain. The status of the regulatory framework is as follows:

- The U.S. Environmental Protection Agency (EPA) promulgated final rule 40 CFR Part 197, Public Health and Environmental Radiation Protection Standards for Yucca Mountain, Nevada (66 FR 32074), on June 13, 2001.

- The NRC promulgated final rule 10 CFR Part 63, Disposal of High-Level Radioactive Wastes in a proposed Geologic Repository at Yucca Mountain, Nevada (66 FR 55732), on November 2, 2001 (see Section 6).

- The DOE promulgated final rule 10 CFR Part 963, Office of Civilian Radioactive Waste Management; General Guidelines for the Recommendation of Sites for Nuclear Waste Repositories; Yucca Mountain Site Suitability Guidelines (66 FR 57298) on November 14, 2001 (see Section 6).

The NRC has identified ten Key Technical Issues (KTIs), topics that the NRC considers most important to evaluating performance of a potential repository at Yucca Mountain. The DOE interactions with the NRC continue to focus on the ten KTIs identified by the NRC and on the associated issue resolution status reports that provide a framework for resolving the KTIs. The DOE and the NRC conducted public meetings on KTIs including topics such as: features, events, and processes screening; igneous activity; preclosure safety; Total System Performance Assessment (TSPA); repository thermal management; and a range of repository operating temperatures. The resolution status of these KTIs is discussed in Section 2.4.

The Project continues to apply substantial resources to addressing cross-cutting quality assurance (QA) issues. Necessary changes will be made at all levels of the program to ensure that important QA issues are expeditiously resolved and that actions are taken to prevent recurrence of significant QA problems.

The Project has committed to the creation and maintenance of a nuclear safety culture and rigorous compliance with QA procedures, two key elements necessary for successful licensing and safe operation of the repository. Improved implementation of quality affecting processes used on the Project is expected to result in a culture of adherence to procedures and in a continuous improvement of the procedures. Activities are currently being carried out in a quality manner; however, these positive quality changes should result in the improved collection and management of data; improved software qualification; and more transparent (defensible) analysis methods, models, and calculations. The importance of sound quality processes and effective implementation of those processes is being emphasized throughout the Project by all management levels within DOE and its contractors.

The status and progress of the QA program and related activities are reported to the NRC on a periodic basis in other forums. The DOE keeps the NRC informed via quarterly QA Management Meetings, semi-annual quality trend reports, submittal of its audit reports, submittal of reports of conditions adverse to quality, and via the NRC On-Site Representative's monthly report of Project activities.

Meetings and other interactions with the NRC's Advisory Committee on Nuclear Waste and with the Nuclear Waste Technical Review Board (NWTRB) provided opportunities to update the Advisory Committee on Nuclear Waste and the NWTRB on technical aspects of the Project and to gain greater understanding of their concerns. The specific details relating to these meetings and interactions are discussed in Sections 2.3 and 2.4.

1.1.4 Planned Studies No Longer Necessary

During this reporting period, the studies and activities were conducted in accordance with the Project baseline scope and schedule for FY 2001. No planned studies were eliminated during the reporting period. More details regarding how Project site characterization activities have evolved over time can be found in Revision 3 and Revision 4 (in progress) of the *Documentation of Program Change*.

1.1.5 Decision Points Reached

The key decision point reached during this reporting period was the initiation of the site recommendation consideration process, as required by Section 114 of the NWPA. This process began on May 7, 2001, with the DOE announcing, in Federal Register notice 66 FR 23013, the initiation of a public comment period on the Secretary of Energy's consideration of the Yucca Mountain site for recommendation as a geologic repository. This announcement was accompanied by the issuance of various program documents and followed by the initiation of public hearings on September 5, 2001 (see Section 2.1 for details).

1.1.6 Modifications to Schedules

The most significant modification to the Program's schedule during this reporting period was the deferral of a decision regarding a potential site recommendation to the President. This milestone, which was planned to be completed by July 2001, was deferred to early 2002 to allow further enhancement to the technical documents that form the basis for a potential site recommendation.

The DOE is also currently evaluating the schedule for submittal of the License Application (LA) to the NRC, if the site is recommended and approved. The evaluation is considering the effects of the final requirements of 10 CFR Part 63, recent interactions with the NRC, and the budgetary constraints of the Congressional appropriations.

1.2 SITE CHARACTERIZATION

1.2.1 Geologic Investigations

Geologic investigation work during this reporting period focused on updating model reports that support the Integrated Site Model, performing natural analogue studies to improve confidence in conceptual models, and performing field investigations to document the characteristics of excavation-induced fractures and evaluate the role of faults as hydrogeologic features.

The three-dimensional Integrated Site Model, which includes the Geologic Framework Model, the Rock Properties Model, and the Mineralogic Model, was expanded with the addition of a fracture model to provide a consistent portrayal of fracture information for use in process models. The NRC has

acknowledged the Geologic Framework Model as an adequate tool for various site-scale analyses, and they intend to use the model to conduct independent analyses of various DOE models that incorporate the Geologic Framework Model.

1.2.2 Natural Analogues

Natural analogues offer one of the multiple lines of evidence that provide a means, independent from TSPA, to build confidence in the ability of the Yucca Mountain site to isolate waste for thousands of years. Natural and anthropogenic analogue studies continued during the second half of FY 2001 to corroborate the modeled processes that operate at scales too large to be measured by laboratory and field-scale experiments. Analogues are also used to demonstrate that modeling codes represent processes correctly (see Section 3.1.2).

Evaluation of measured seepage in caves at Altamira, Spain, and Kartchner Caverns, Arizona, indicated that less than 2 percent of the available moisture became seepage, and that most infiltration does not become seepage. These natural analogues demonstrate that much of the seepage that does occur stays on the roof and walls rather than dripping. Furthermore, if relative humidity is kept below 100 percent through ventilation, seepage of liquid water is reduced or completely suppressed.

1.2.3 Geologic Field Investigations

Geologic field investigations focused on characterization of excavation-induced fractures and hydrogeological features of faults that could affect groundwater flow (see Section 3.1.3). A study to observe and document excavation-induced fractures was performed in the Enhanced Characterization of the Repository Block (ECRB) Cross Drift where all three excavation methods (tunnel boring machine (TBM), alpine miner, and drill-and-blast) had been used. In general, the impact of excavation on the formation of fractures was minimal. The study indicated that the TBM-induced fractures generally penetrated only a few centimeters into the tunnel wall; Alpine miner-induced fractures penetrated a few centimeters to tens of centimeters; and drill-and-blast excavation produced fractures that penetrated tens of centimeters. A recent study of the hydrological features of faults concluded that faults at Yucca Mountain could affect groundwater flow by acting as barriers, conduits, and combined conduit/barriers. In general, faults within the potential repository block may increase the potential for fluid flow by increasing bulk intrablock fracture porosity.

1.2.4 Near-Field Environment

Near-field environment work focused on the coupled effects of thermal-hydrological (TH), thermal-hydrological-chemical (THC), and thermal-hydrological-mechanical (THM) processes on seepage into emplacement drifts. Model analyses of the Drift Scale Test showed that wall temperatures above the boiling temperature of water reduces the amount of water flow that reached the emplacement drift, because of the development of a dry superheated zone around the drifts. The superheated zone persists for a limited time, and eventually re-wetting of the drift wall would occur as the system cools.

The Drift Scale Test, which is in its fourth year of heating, continued with collection of thermal, hydrological, mechanical, and chemical response data. In June 2001, a total of eight new rock samples were obtained from within three boreholes to investigate the mineralogic/petrologic response to the thermal-hydrological environment near the boiling zone. Chemical compositions of minerals in rock samples obtained from three boreholes indicate that heating has produced three products tentatively identified as amorphous silica, a calcium sulfate phase (gypsum or anhydrite), and a calcium-rich phase that is probably calcite. Strontium and uranium isotopic compositions in water samples collected from

the Drift Scale Test continued to show strong similarity to ambient pore water, indicating that heating has had little impact on the isotopic composition of these elements in water.

1.2.5 Site Unsaturated Zone Flow and Transport

The Busted Butte unsaturated zone (UZ) field test was designed to measure solute and colloid movement through the Calico Hills nonwelded to moderately welded tuff layers that underlie the potential repository horizon. The test involved tracer injection tests, laboratory analysis of tracer samples, analysis of rock cores, and numerical modeling to test conceptual models. The 830-day Phase 2 tracer-injection test, completed on October 30, 2000, utilized dissolved species of Ni, Co, and Mn as surrogates for the dissolved species of radionuclides Am, Pu, Tc, and Np under the Busted Butte test conditions. Analysis of the first of five cores from the vicinity of the injection holes indicates that reactive metals (Ni, Co, and Mn) were restricted to the environment adjacent to the injectors (tenths of meters). Cobalt traveled approximately 0.3 m below the injector, while Ni concentrations were observed to be above the background concentration approximately 0.15 m below the injector. Based on these tests, and model simulations, colloid transport in the UZ was predicted to be much less than in the saturated zone (SZ). Long travel distances for any significant volume of colloids through the UZ is unlikely for colloids larger than 200 nm, but there is not enough information to evaluate the transport of smaller colloids.

Results of drift-to-drift seepage rate threshold tests indicate that longer-duration tests in sealed niche conditions provide the most useful data sets for the seepage calibration and other performance-assessment models. Analysis of other niche seepage tests indicates that the lower lithophysal zone of the TSw has higher air-permeability than the middle nonlithophysal zone and that the relative changes in permeability before and after niche excavation are smaller in the lower lithophysal zone. Work continued on the Alcove #8/Niche 3 test, which is designed to evaluate migration and seepage from the ECRB Crossover Alcove (Alcove #8) into Niche 3 in the Exploratory Studies Facility (ESF) Main Drift along a fault.

Systematic hydrological characterization of air-permeability and seepage in the ECRB Cross Drift continued using the automatic, rail-mounted borehole testing and data-collection system. Drift ceiling seepage observations indicated that the participation of the lithophysal cavities in liquid flow is small. Furthermore, evaporation did not account for all the difference between injected water and collected seepage water, indicating that a seepage threshold exists in the lower lithophysal zone of the TSw.

Moisture monitoring between the bulkheads in the ECRB Cross Drift continued during the reporting period with temperature and relative humidity measurements behind the bulkheads being taken from January 22, 2001, to July 9, 2001. When power was cut off to the TBM in April 2001, temperatures began falling behind the second and third bulkheads and the temperature gradient toward the end of the ECRB Cross Drift diminished. The appearance of moisture behind the third bulkhead and the smaller amount of moisture between the second and third bulkheads indicate that as the temperature gradient decreased, observable moisture tended to move toward the TBM.

Studies of the origin of secondary calcite and silica deposits continued to provide insights about past and present liquid-water flow through the UZ. The sporadic distribution of secondary mineral deposits on no more than 6 percent of fractures (on footwalls) and in 1 to 42 percent of lithophysal cavities (on floors), was consistent with simulations of fracture flow processes in a UZ setting. The distribution and restriction of deposits to footwalls and floors were inconsistent with a rise in the water table, or even localized hydraulic saturation, which would indiscriminately and universally mineralize all fractures and cavities in the regions of flooding. Data from fluid inclusion studies indicated that the rock mass probably has been unsaturated throughout secondary mineral deposition and at near-ambient temperatures for at least the last 2 million years, and possibly as much as 4 million years.

Project scientists continued analyses of fluid inclusions in secondary calcite deposited in the UZ at Yucca Mountain to determine the conditions under which the minerals were formed. The ages, based on the $^{235}U/^{207}Pb$ ratios for fourteen sub-samples, range between 1.88 ± 0.05 and 9.7 ± 1.5 million years with most ages older than 6 to 8 million years. These data indicate that fluids with elevated temperatures have not been present in the UZ at Yucca Mountain for about 1.9 million years and more likely 6 to 8 million years.

The ^{36}Cl validation study continued with evaluation of rock-sample leaching methods and selection of the preferred method. The path forward includes selection and independent re-analysis of samples for Cl, Br, and SO_4 concentrations and evaluation of the two resulting data sets to determine whether the ^{36}Cl values are consistent and provide the same information with respect to the existence of fast water-flow pathways.

During a teleconference held in June 2001 between the DOE and the NRC, DOE agreed to continue the monitoring in UZ surface-based boreholes UE-25 UZ#5, UE-25 UZ#4, and USW NRG-7a until a final evaluation of the data could be made.

Isotopic compositions of core-water samples from boreholes USW SD-6 and USW WT-24 indicated that relatively young water has been introduced at depth at the basal vitrophyre of the Topopah Spring Tuff and near the Calico Hills Formation/Prow Pass Tuff contact. This young water probably was derived from lateral fracture flow through the Topopah Spring welded unit from the Solitario Canyon fault to the west and recharge from the Prow of Yucca Mountain to the north.

1.2.6 Site Saturated Zone Flow and Transport

SZ work included compilation of borehole logs and geochemical analyses for major anions, major cations, trace elements, and the oxidation states of As, Se, and Sb for samples from the Nye County drill holes. Hydraulic and tracer testing and radionuclide transport testing in alluvium continued at the Alluvial Testing Complex.

Three new geologic cross sections that extend across Fortymile Wash and southern Yucca Mountain were completed. These cross sections integrate borehole data from the Nye County Early Warning Drilling Program (NC-EWDP), Phase I and Phase II, surface-based geophysics, and surface geologic mapping. Information derived from these cross sections is intended to aid in revising the site and regional hydrologic framework models and in helping to predict subsurface geology at future Nye County drilling sites.

Several key efforts in the Death Valley regional flow system modeling project continued during the reporting period with particular emphasis on database improvements, construction of the transient hydrogeologic framework model, refinements to the flow modeling system, and preparation of reports on the steady-state hydrogeologic framework and groundwater flow models.

Other SZ field investigations included water-level monitoring. The water-level report for calendar year 1999 was revised to incorporate technical review comments and submitted for further processing. Several quarterly data packages for years 2000 and 2001 for manual and continuously recorded water-level measurements were processed and submitted to the Technical Data Management System. All water-level monitoring activities transitioned from the U.S. Geological Survey (USGS) to the University of Nevada Las Vegas Harry Reid Center in September 2001.

1.2.7 Engineered Barrier System Testing

Engineered barrier system (EBS) testing during the reporting period focused on ventilation testing to support design of the repository ventilation system, and on natural convection and thermal conductivity testing to support the predictions of the heat and temperature distributions in the drifts. This information is needed for performance assessment and for validation of the geochemical model (see Section 3.5).

Phase 2 of the quarter-scale ventilation test series was completed. Each of the 16 test runs lasted between three and ten days. Data processing is currently in progress, but preliminary results indicate that the ventilation system model being used for design is able to accurately predict test results. Data from this test series establishes the credibility of the model and the Project's ability to design and apply ventilation systems to manage thermal loads in the repository.

Thermal conductivity field tests in the lower lithophysal unit (Tptpll) were performed in the ECRB Cross Drift during the reporting period. These field thermal conductivity measurements include the effects of lithophysae too large to be included in laboratory samples. Initial results from the field test program yielded a thermal conductivity of 1.74 W/m K, which is within the range of thermal conductivities used in the *FY01 Supplemental Science and Performance Analyses* (SSPA) Volumes 1 and 2. The SSPA used a thermal conductivity of 1.75 W/m K for the lower lithophysal unit based on a mean porosity of 12.5 percent and a mean saturation of 80 percent.

1.2.8 Disruptive Events

Disruptive events work during the reporting period addressed igneous issues related to a range of thermal operating modes for a potential repository and also addressed issues raised in meetings with the NRC. An approach using scaling factors to evaluate the effect of different repository footprints on probabilities of volcanic intersection and on the number of waste packages (WPs) affected by igneous activity was developed and presented to the NRC. For the igneous eruption scenario, new waste particle size distributions were defined for the TSPA sensitivity analyses. The minimum waste particle size was reduced by a factor of one-half and the maximum waste particle size was increased by a factor of two. Also for the igneous eruption scenario, a new wind speed distribution was developed that provides wind speeds at higher altitudes, consistent with the height of potential eruption ash plumes.

1.3 DESIGN AND CONSTRUCTION

During this reporting period, the Project continued to develop repository design requirements, test the waste form and WP materials, evolve the WP design, evolve the surface and subsurface repository designs, and construct sites for testing activities in the ESF. Details of the advances in these areas are described in Sections 4.1 through 4.7.

1.3.1 Design Requirements

The Project continued to develop and revise *the Monitored Geologic Repository Project Description Document* and the *Yucca Mountain Site Characterization Project Requirements Document (YMP-RD)*.

1.3.2 Waste Form Testing

The following Analysis and Model Reports (AMRs) were issued during the reporting period:

- Defense High Level Waste Glass Degradation
- Secondary Uranium-Phase Paragenesis and Incorporation of Radionuclides into Secondary Phases
- Summary of Dissolved Concentration Limits.

Tests involving humid air exposure of two samples of perforated commercial spent fuel rods showed that the cladding on both samples unzipped at a rate faster than the range used in the S&ER. However, the observed rate of unzipping was consistent with the upper bound value used in the SSPA. This issue is planned to be resolved by updating the unzipping model and incorporating it in the next revision of the cladding degradation AMR, *Clad Degradation – Summary and Abstraction*.

1.3.3 Waste Package Materials Testing

An engineering calculation, *Plugging of Stress Corrosion Cracks by Precipitates,* was completed. The results of the calculations showed that stress corrosion cracks could become filled with precipitation of minerals (primarily calcite) and corrosion products in less than 1,000 years after the cracking occurs. The implication of this result is significant in that it allows the drip shield to maintain its intended function of diverting dripping water away from the WP. In the case of the WP, crack plugging will significantly reduce the rate of water ingress, which in turn reduces the rate of radionuclide release from the WP.

Also during this reporting period, a Peer Review of the Waste Package Materials Performance was initiated with a meeting on May 23, 2001. At the meeting, Project personnel made presentations on the status of the WP materials performance issues and path forward work to address these issues. On July 24, 2001, the Peer Review Panel held an open meeting in Cleveland, Ohio, to hear presentations on WP corrosion topics presented by non-Project investigators. The Peer Review Panel also held a number of sub-group meetings to develop a better understanding of the Project technical basis in specific areas of material performance such as localized corrosion, stress corrosion cracking, etc. Based on these meetings and a review of Project documents, the Peer Review Panel prepared an Interim Report that includes a number of recommendations for additions and changes in the Project's WP development program. The report's preliminary findings were presented at a public meeting on September 25, 2001. Overall, the preliminary findings support the Project's selection of WP materials and the testing and modeling approach used for the development of the technical bases.

1.3.4 Waste Package Design

The *Waste Package Project FY-01 Closure Methods Report* was completed during this reporting period. This report summarizes the closure weld development work done to identify primary closure welding processes for the SR WP design, evaluate the Alloy 22 (UNS N06022) middle-lid joint design, provide a closure weld facility conceptual design and process sequence, and determine minimum detectable flaw size. This task included the welding of 240 inches of specimen plates for the materials testing program.

The *Waste Package Operations Fabrication Process Report* was revised to incorporate information from the FY 2001 closure weld program and to update the other information in the document. The objective of this task was to identify various manufacturing methods that may be used to fabricate the WP, drip shield,

and emplacement pallet at whatever manufacturing facilities are awarded the fabrication contracts. This report provides recommended methods and alternative methods for these operations.

The *Waste Package Design Methodology Report* was issued to describe the analytical methods and processes used to establish the integrity of the various WP, emplacement pallet, and drip shield designs. The report describes the basic features and appropriateness of the methodology used in criticality, risk-informed, shielding, source term, structural, and thermal analyses. The processes are defined whereby input values and assumptions flow through the application of those methods to obtain designs that ensure defense-in-depth as well as satisfy requirements on system performance.

Section 4.4.1 describes the content of three additional reports issued during this reporting period, and Section 4.4.2 describes the content of 23 calculations completed during the reporting period.

1.3.5 Surface Design

The "Design Dose Rate" (a memorandum) was prepared during this reporting period. This preliminary radiation design guide is to be used Project-wide to provide a consistent reference for a design occupational dose rate limit of 1,000 mrem/yr, based on expected occupancy factors. In addition, the occupational dose rate limit will be subject to review to ensure that the doses are as low as reasonably achievable per 10 CFR 20.1003.

1.3.6 Repository Design

The flexible repository design concept was advanced during this reporting period to include the low-temperature operating mode. The low-temperature operating mode design is supported by the following design documents:

- *Lower-Temperature Subsurface Layout and Ventilation Concepts*, which integrates the ventilation system design with the subsurface facilities design
- *Overall Subsurface Ventilation System*, which provides a basis for ventilation system layout and design to support flexible thermal operating mode concepts
- *Thermal Management Analysis for Lower-Temperature Design*, which provides the thermal basis for the lower-temperature design and ventilation
- *Shaft Siting and Configuration for Flexible Operating Mode*, which evaluates the suitability of the shaft locations specified in the lower-temperature subsurface layout.

The ground support system response to a low-temperature repository condition was evaluated and documented in *Ground Control for Emplacement Drifts for SR*. The analysis evaluates the ground control approach in emplacement drifts for both low-temperature and high-temperature repository operating modes.

The *Gantry Structural/Control System Analysis* was completed. The *Lower Temperature Invert Design for Diffusion Barrier* was also completed and it outlines the options for including diffusive barrier material in the invert designs.

1.3.7 Exploratory Studies Facilities and Construction

Geochemical Analysis–The interaction between the EBS (WPs, drip shields, etc.) and the host rock (minerals, contained water and gases) at temperatures well above natural ambient temperatures is being investigated to assess the performance of the potential repository for long-term containment of nuclear waste. Core samples obtained from the potential repository block in the ECRB Cross Drift were analyzed to determine the geochemical uniformity of the rock by comparing the relative amounts of major and trace elements. Duplicate analyses of 20 samples confirmed the compositional uniformity of the Topopah Spring Tuff.

The major elements and trace elements in 27 samples of dust collected throughout the ESF have been analyzed to investigate the interaction of water and rock dust on EBS materials.

Construction–The construction of the ESF Niche 5 Collection Wings was completed. The underground lighting system in the ESF is currently being upgraded and is expected to be complete during FY 2002. Construction of the ESF Switch Gear Building continued through this reporting period and is scheduled to be completed in FY 2002. The ESF Visual Warning System drawings were completed and issued during this period.

1.4 REPOSITORY PERFORMANCE

During this reporting period, the Project accomplished several advances in preclosure radiological safety assessment, postclosure performance assessment, and performance confirmation. These advances are described fully in the Sections 5.1, 5.2, and 5.3, respectively.

1.4.1 Preclosure Radiological Safety Assessment

The *Preliminary Preclosure Safety Assessment for Monitored Geologic Repository Site Recommendation* was updated to include an analysis of lower repository temperature operational modes (and corresponding longer preclosure operating periods). This safety assessment work includes the identification of facility hazards and potential initiating events, identification of Monitored Geologic Repository (MGR) design basis events (DBEs), evaluation of DBE occurrence frequencies and consequences, and the identification of those structures, systems, and components (SSCs) important to safety. This report also provides the MGR strategies for criticality safety, radiation protection, fire protection, and management of low-level radioactive waste.

A DBE-related analysis, *DOE SNF BDBE Dose Calculations*, was also issued during this reporting period to evaluate the dose consequences of a beyond DBE associated with DOE spent nuclear fuel (SNF). The beyond DBE calculation included a non-mechanistic initiating event and the sequence of events that follow to cause a radiological release. The beyond DBE calculation resulted in an unmitigated (i.e., no high-efficiency particulate air filtration) dose that was below regulatory limits.

Technical exchange meetings were held with the NRC to discuss the development of Preclosure Safety Analysis (PSA). Four items were identified as DOE commitments as part of the NRC/DOE agreements resulting from the technical exchange; they included an aircraft hazards plan and vicinity map for LA; the PSA guide; an update to the QA procedure for the classification of SSCs important to safety; and an update to the analysis of tornado winds and tornado-driven missiles.

1.4.2 Postclosure Performance Assessment

Performance Assessment–During this reporting period the SSPA Volumes 1 and 2 were developed and issued. SSPA Vol. 1 presents the new information developed since completion of the initial AMRs, process model reports (PMRs), the *Total System Performance Assessment for Site Recommendation* (TSPA-SR), and the S&ER. SSPA Vol. 2 describes the supplemental TSPA analyses conducted using the updated information documented in SSPA Vol. 1. SSPA Vol. 2 addresses the performance of a potential repository at Yucca Mountain considering the most recent scientific data, updated models, quantification of uncertainty, and a lower-temperature operating mode. The *Total System Performance Assessment–Analyses for Disposal of Commercial and DOE Waste Inventories at Yucca Mountain, Mountain–Input to Final Environmental Impact Statement and Site Suitability Evaluation* was also issued during this reporting period. This report documented the estimated effects on long-term dose due to the potential disposal of commercial SNF, DOE SNF, HLW, DOE Greater than Class C, and Special Performance Assessment Required nuclear waste at the potential repository.

Engineered Barrier System–Presentations were made to the NWTRB in May 2001, June 2001, and September 2001 that addressed quantified and unquantified uncertainties, thermal operating modes, and thermal-hydrologic and thermal-mechanical effects. Presentations on the contents of the SSPA were also made to the NRC in August 2001.

UZ Flow and Transport–The focus of the UZ flow and transport modeling investigations has been redirected to the preparation of a number of new models and the performance of numerous simulations to support sensitivity analyses of unquantified uncertainties and the flexible operating mode. The results of the numerical simulations have been summarized in SSPA Vol. 1 Sections 3 (UZ Flow), 4 (Seepage), and 11 (UZ Transport). Presentations were made to the NRC, at technical exchange meetings, on TSPA and integration and on the range of thermal operating conditions. Also, presentations were made to the NWTRB in June 2001, which addressed UZ flow, transport, and coupled processes that are addressed in the SSPA.

SZ Flow and Transport–The SSPA Vol. 1 presents the new information, which includes:

- New data and analyses to quantify previously unquantified uncertainties and uncertainty ranges
- New data and development work at the process-model level
- Multiple lines of evidence, including natural analogues, hydrochemical and isotopic analyses, single-well tracer testing at the Alluvial Testing Complex, and transport studies on blocks of intact tuff mined from the Busted Butte Unsaturated Zone Facility.

Biosphere–The Biosphere technical effort during this reporting period focused on analyses and documentation found in Section 13 of the SSPA Vol. 1, and includes:

- The sensitivity of Biosphere Dose Conversion Factors (BDCFs) to the definition of the receptor
- An evaluation of the uncertainties associated with radionuclide removal from soil by leaching
- The uncertainty in groundwater usage by the hypothetical community
- The inhalation pathway model update
- The impacts of climate change on BDCFs
- Derivation of the scenario-specific BDCFs for ^{79}Se and ^{237}Np.

Technical exchange meetings with the NRC on the KTI involving the biosphere yielded agreements with the NRC on resolution of all biosphere issues.

Disruptive Events–Disruptive events work performed during the reporting period included the following:

- The use of scaling factors to evaluate the effect of different repository footprints on the probabilities of volcanic intersection and on the number of WPs affected by igneous intrusion
- New waste particle size distributions for TSPA sensitivity analyses
- A new wind speed distribution that provides wind speeds at higher altitudes for the igneous eruption scenario.

A new sensitivity analysis showed the relative dose from WPs in two different damage zones: a few packages completely compromised nearest a dike intrusion into a drift; and a greater number of partly damaged WPs further away from the dike. The completely compromised packages nearest the dike intrusion resulted in the greater contribution to the dose.

1.4.3 Performance Confirmation

The performance confirmation program, which began during site characterization and continues until permanent closure, includes activities to collect and analyze repository performance data to ensure that conditions encountered, and changes in those conditions, are within the limits to be stated in the LA. The performance confirmation program will determine whether the natural systems, engineered systems, and system components function as intended and anticipated.

The *Performance Confirmation Plan* and the *Monitored Geologic Repository Test & Evaluation Plan* are being updated due to revision of Project requirements, the evolution of the design concept, and the finalization of 10 CFR 63 and 40 CFR 197.

INTENTIONALLY LEFT BLANK

SECTION 2 – PROGRESS TOWARD NEAR-TERM OBJECTIVES

During this reporting period, Project activities continued to support major near-term objectives to enable the Secretary of Energy to determine whether Yucca Mountain will be recommended as the site of a geologic repository. Before deciding whether to recommend the site to the President, the Secretary will consider the information presented in the SR decision materials being prepared, including the comments received as part of the public involvement process. The activities related to the potential site recommendation are discussed in Section 2.1.

Work also continued on those activities related to preparation of the Final EIS, including the provision of opportunities for public involvement. In accordance with the NWPA [101681][3], the Final EIS is to be included as part of the comprehensive statement of the basis for recommendation of the site. These activities are discussed in Section 2.2.

Progress was made by the EPA and the NRC toward finalizing the regulatory framework and by the DOE in finalizing site suitability guidelines. These activities are discussed in Section 2.3. Information regarding issue resolution, planned studies no longer necessary, decision points reached, and modifications to schedules are contained in Sections 2.4 through 2.7, respectively.

2.1 SITE RECOMMENDATION

The NWPA [101681] requires the Secretary of Energy to determine the suitability of the Yucca Mountain site as a nuclear waste repository and, if the determination is positive, forward a recommendation regarding siting of the proposed repository to the President. To support the decision-making process, a suite of documents intended to provide sufficient information to allow the Secretary to make the required decision was defined. The documents that will be provided to the Secretary of Energy include:

- Revision 1 of the S&ER (in progress, see Appendix B). A report describing a repository at Yucca Mountain, including preliminary engineering specifications, description of the waste form and packaging, discussion of the data obtained from site characterization activities relating to the safety of the site, and a description of the analyses performed to evaluate the safety of the potential repository. This report provides the information identified in the NWPA, Sections 114(a)(1)(A-C).

- The *Final Environmental Impact Statement for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada* (in progress, see Appendix B), per the NWPA, Section 114(a)(1)(D).

- *Yucca Mountain Site Suitability Evaluation* (in progress, see Appendix B). An evaluation of the Yucca Mountain site's performance against the DOE's site suitability guidelines, 10 CFR 963 ([156908] 66 FR 57298).

[3] References are cited in text by DIRS (Document Input Reference System) number and numerically sorted by DIRS number in the reference list. The unique DIRS number is placed in the text before the author-date callout (e.g., ([155950] CRWMS M&O 2000).

- *Site Recommendation Comment Summary Document* (in progress, see Appendix B). A delineation of the views and comments of the governor and legislature of any state, or the governing body of any affected Indian tribe[4], together with the response of the Secretary of Energy to such views and comments, as required by the NWPA Section 114(a)(1)(F). In addition, the comment summary document will present comments from members of the U.S. House and Senate; Nevada State and local elected officials; elected officials from Inyo County, California; representatives of Native American tribes; and members of the general public. Individual responses will be provided for comments received from government entities, and summary responses will be provided for comments received from the general public.

- NRC preliminary comments ([156977] Meserve 2001) concerning the extent to which the at-depth site characterization analysis and the waste form proposal for Yucca Mountain seem to be sufficient for inclusion in any application to be submitted by the Secretary of Energy for licensing of the Yucca Mountain site as a repository. The document provides the information required per the NWPA, Section 114(a)(1)(E).

- Other documents, such as updates to the total system life cycle cost report ([153255] DOE 2001) and fee adequacy report ([153257] DOE 2001), as deemed appropriate.

During this reporting period, several significant events occurred related to the site recommendation process. On May 7, 2001, the DOE announced ([155009] 66 FR 23013) the initiation of a public comment period on the Secretary of Energy's consideration of the Yucca Mountain site for recommendation as a geologic repository. In conjunction with the announcement, the DOE issued the S&ER ([153849] DOE 2001), summarizing the scientific and technical information compiled to date regarding the preliminary design and performance attributes of a potential geologic repository at the Yucca Mountain site. Three other reports were released at about the same time: a Supplement to the Draft EIS ([152985] DOE 2001), an updated total system life cycle cost report ([153255] DOE 2001], and an updated fee adequacy report ([153257] DOE 2001).

On August 21, 2001, the DOE announced ([156969] 66 FR 43850) the issuance of another report, the *Yucca Mountain Preliminary Site Suitability Evaluation* ([155734] DOE 2001). This report contains a preliminary evaluation of the suitability of the Yucca Mountain site for development as a geologic repository based on the DOE's then-proposed site suitability guidelines ([124754] 64 FR 67054). The report is based on information contained in the S&ER ([153849] DOE 2001), supplemented by the most current technical information available at that time, including evaluation of a range of thermal operating modes for the potential repository.

With Federal Register notice 66 FR 43850 ([156969] 66 FR 43850), the DOE also announced the scheduling of public hearings, pursuant to Section 114(a)(1) of the NWPA [101681], and the date for the closure of the public comments period (September 20, 2001). A public hearing was held in North Las Vegas on September 5, 2001, with videoconference connections to Reno, Carson City, and Elko, Nevada. A satellite link was also established with Washington D.C. to allow the Nevada Congressional delegation an opportunity to provide its views regarding the Secretary of Energy's consideration of the Yucca Mountain site. Because of the September 11, 2001, terrorist attacks on the United States, the DOE issued a Federal Register notice ([157061] 66 FR 49372) on September 27, 2001, postponing the Amargosa Valley and Pahrump, Nevada, public hearings to October 10 and October 12, 2001, respectively. The end of the public comment period was also postponed to October 19, 2001 ([156973] 66 FR 51027).

[4] At the time of this report, no Indian tribe has been designated as "affected" within the definition of the applicable laws and regulations.

In addition to the public hearings required by the NWPA, the DOE also announced ([157159] 66 FR 50423) that it would conduct 29 field hearings in Nevada and in Inyo County, California, during the first two weeks of October to collect comments on the Yucca Mountain Project from the citizens in these areas. The Yucca Mountain Science Center in Las Vegas, Nevada, was also established as an extended hearing facility starting on September 26, 2001, and running until the end of the public comment period, to receive public testimony from any citizen wishing to provide official comments ([156972] 66 FR 50176).

As of the end of this reporting period, approximately 3,678 comments had been received, in the form of letters, faxes, e-mails, and transcripts. The responses to these comments, and to the various issues raised in these comments, will be incorporated into *Site Recommendation Comment Summary Document* (in progress, see Appendix B).

2.2 ENVIRONMENTAL IMPACT STATEMENT

The NWPA, Section 114(f)(1) [101681], requires that a Final EIS serve as one of the supporting elements for a decision on site recommendation and that the Final EIS accompany any Secretarial recommendation to the President.

The DOE issued the *Supplement to the Draft Environmental Impact Statement for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada* ([152985] DOE 2001) updating information in the *Draft Environmental Impact Statement for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada* ([105155] DOE 1999). The supplement evaluates potential environmental impacts that could occur, based on the design and range of possible operating modes presented in the *Yucca Mountain Science and Engineering Report* ([153849] DOE 2001). The supplement addressed only changes to the repository design and operating modes discussed in the Draft EIS.

As described in the Draft EIS ([105155] DOE 1999), the repository design has continued to evolve, reflecting evaluations of design options and ways in which to operate the repository (operating modes) that would reduce uncertainties and improve long-term performance and operational safety and efficiency. While aspects of the design have continued to evolve, the basic elements of the proposed action to construct, operate, monitor, and eventually close a geologic repository at Yucca Mountain remain unchanged from the design discussed in the Draft EIS.

Public hearings on the Supplement to the Draft EIS ([152985] DOE 2001) were conducted in Amargosa Valley, Nevada, on May 31, 2001; in Las Vegas, Nevada, on June 5, 2001; and in Pahrump, Nevada, on June 7, 2001. The public comment period for the EIS supplement started on May 11, 2001, and closed on July 6, 2001. An extension was provided to August 13, 2001, for those individuals that did not receive the document at the time of the initial distribution. DOE received 490 comment documents containing approximately 1,913 comments. As the Final EIS is prepared, the DOE will consider the comments made during the public comment periods on the Draft EIS ([105155] DOE 1999) and on the Supplement to the Draft EIS.

2.3 REGULATORY FRAMEWORK, INTERACTIONS, AND STRATEGY

2.3.1 Status of the Regulatory Framework

The Energy Policy Act of 1992 [100017] signaled a broad shift from a generic to a site-specific regulatory framework for evaluation of and decision-making about a potential repository at Yucca Mountain.

Finalizing this regulatory framework is central to determining the suitability of the Yucca Mountain site for development as a repository in a manner that protects both public health and safety and the environment. The status of the regulatory framework is as follows:

- The EPA proposed a regulatory standard specific to the Yucca Mountain site, 40 CFR Part 197 ([105065] 64 FR 46976), on August 27, 1999. The EPA promulgated the final rule on 40 CFR 197, "Public Health and Environmental Radiation Protection Standards for Yucca Mountain, Nevada," in the Federal Register on June 13, 2001 ([155216] 66 FR 32074); it became effective on July 13, 2001 ([155238] 40 CFR 197).

- The NRC proposed a site-specific regulation, 10 CFR Part 63 ([101680] 64 FR 8640) on February 22, 1999. The draft of the final 10 CFR 63 was provided by the NRC to the Office of Management and Budget on September 21, 2001, for final review prior to publication in the Federal Register. This version incorporated the EPA standard from 40 CFR Part 197 as well as comments incorporated from the public comment period. At of the end of this reporting period, the final 10 CFR Part 63 had not been published (see Section 6).

- The DOE issued a revised proposal to amend its site suitability guidelines for Yucca Mountain, 10 CFR Part 963 ([124754] 64 FR 67054), on November 30, 1999, based on the proposed EPA and NRC regulations and on advances in technology. In accordance with Section 112(a) of the NWPA, the DOE must obtain the concurrence of the NRC prior to final issuance of the guidelines. At the end of this reporting period, the guidelines were undergoing NRC concurrence review, and the final 10 CFR Part 963 had not been published (see Section 6).

The DOE is taking an active role in implementing the Licensing Support Network Rule ([103537] 10 CFR 2, Subpart J). The Licensing Support Network is a web-based system that makes documentary material available electronically to the public and to participants in any proceedings associated with an application for authorization to construct a geologic repository, if such an application is submitted. Work continues to focus on an overall Project implementation strategy and plans for development of the electronic system and procedures to ensure compliance with Subpart J.

2.3.2 Regulatory Interactions

Although near-term work will continue to focus on activities necessary to enable the Secretary of Energy to make a decision regarding the suitability of the Yucca Mountain site as a geologic repository, the DOE continues to interact with the NRC to ensure that Project activities are consistent with NRC expectations for submittal of a high-quality repository LA, if the Yucca Mountain site is recommended and approved as a suitable repository site.

The NRC has identified ten KTIs, topics that the NRC considers important to evaluating performance of a potential repository at Yucca Mountain. The DOE interactions with the NRC continue to focus on the KTIs and on the associated NRC issue resolution status reports that provide a framework for addressing and resolving the KTIs. Issues are closed by the NRC if the DOE approach and available information acceptably address Project questions such that no information beyond what is currently available will likely be required for regulatory decision making at the time of initial license application. Issues are "closed-pending" if the NRC staff has confidence that the DOE proposed approach, together with the DOE agreement to provide the NRC with additional information (through specified testing, analysis, etc.), acceptably addresses the NRC's questions such that no information beyond that provided or agreed to will likely be required at time of initial license application. Issues are "open" if the NRC has identified questions regarding the DOE approach or information, and the DOE has not yet acceptably addressed the questions or agreed to provide the necessary additional information in the license application. The DOE

and the NRC conducted public meetings on KTIs including topics such as: features, events, and processes screening; igneous activity; preclosure safety; TSPA; repository thermal management; and a range of repository operating temperatures. The resolution status of these KTIs is discussed in Section 2.4. Technical exchange meetings with the NRC will continue to be held to update the NRC on new information that relates to the KTIs.

The Project continues to apply substantial resources to addressing cross-cutting QA issues. Necessary changes will be made at all levels of the program to ensure that important QA issues are expeditiously resolved and that actions are taken to prevent recurrence of significant QA problems.

The Project has committed to the creation and maintenance of a nuclear safety culture and rigorous compliance with QA procedures, two key elements necessary for successful licensing and safe operation of the repository. Improved implementation of quality affecting processes used on the Project are expected to result in a culture of adherence to procedures and in a continuous improvement of the procedures. Activities are currently being carried out in a quality manner; however, these positive quality changes should result in the improved collection and management of data; improved software qualification; and more transparent (defensible) analysis methods, models, and calculations. The importance of sound quality processes and effective implementation of those processes is being emphasized throughout the Project by all management levels within DOE and its contractors.

The status and progress of the QA program and related activities are reported to the NRC on a periodic basis in other forums. The DOE keeps the NRC informed via quarterly QA Management Meetings, semi-annual quality trend reports, submittal of its audit reports, submittal of reports of conditions adverse to quality, and via the NRC On-Site Representative's monthly report of Project activities.

The QA and management meetings with the NRC were conducted in June and September 2001. Interactions with the Advisory Committee on Nuclear Waste continued to provide the status of Project activities and address issues raised by Committee. The meetings provided multiple opportunities for DOE to explain the bases for Project positions and decisions and to gain greater understanding of the concerns of the Committee.

2.3.3 Issue Resolution

The DOE and the NRC held several interactions during this reporting period on topics pertaining to the NRC KTIs. Each technical exchange meeting on these KTIs has resulted in identifying agreement items that must be met to close the “closed-pending” issues. For the KTI meetings held to date with the NRC, all of the associated KTI subissues have a “closed” or “closed-pending” status. The previously “open” Subissue 2 of the Igneous Activity KTI was put into the “closed-pending” status as a result of the igneous activity technical exchange in September 2001.

2.3.4 Repository Licensing Strategy

A key consideration for a possible site recommendation and for NRC licensing decisions for a HLW repository at Yucca Mountain is the ability of the site to protect the public and the environment from any undue risk during operations and after permanent closure. The DOE is preparing preclosure and postclosure safety cases for the potential repository system. The latest revision of the *Repository Safety Strategy* ([154951] CRWMS M&O 2001) provides a status of activities designed to support the

defensibility and credibility of the safety cases, and identifies a strategy for preparing an LA. Since issuance of the latest revision to the *Repository Safety Strategy*, the set of activities has been replanned and the strategy for moving forward to a possible LA is changing. The *Repository Safety Strategy* will be supplemented by a new licensing strategy. The purposes of the licensing strategy are:

- To identify the strategy, processes, mechanics, guidelines, and documentation approach for developing a license application that demonstrates adequate protection of the health and safety of employees and the general public and adequate protection of the environment.

- To describe the concepts, philosophy, overall approach, and methods that will be used to construct and articulate the Yucca Mountain repository safety case. The licensing strategy will define and describe the elements of the preclosure and postclosure safety cases, and will be the single and common source for the Project position on strategic licensing issues and provide a glossary of regulatory terms for consistent use in the licensing context.

- To provide guidance regarding the framework within which programmatic requirements are identified and implementing details are developed.

- To focus the work that is necessary to develop an LA and to resolve licensing issues.

2.4 NUCLEAR WASTE TECHNICAL REVIEW BOARD INTERACTIONS

During the reporting period, interactions with the NWTRB provided an opportunity to update the NWTRB on technical aspects of the Project. These interactions also focused on the NWTRB's four priority areas. As summarized in their April 2001 Report to Congress ([156474] NWTRB 2001), these four priority areas are:

- Meaningful quantification of conservatisms and uncertainties in the DOE's performance assessments.

- Progress in understanding the underlying fundamental processes involved in predicting the rate of WP corrosion.

- An evaluation and comparison of the base-case repository design with a low-temperature design.

- Development of multiple lines of evidence to support the safety case of the potential repository. These lines of evidence should be derived independently of performance assessment, and thus, not subject to the limitations of performance assessment.

On April 13, 2001, the NWTRB held an Ad Hoc Panel Discussion of the use of multiple lines of evidence to evaluate the safety of a potential repository at Yucca Mountain. This helped to clarify the NWTRB's expectations on the use of multiple lines of evidence.

On May 8-9, 2001, the NWTRB held a Full Board Meeting, focusing on their four priority areas, total system performance assessment, and new information from the science program, including fluid inclusion studies. This meeting provided an opportunity for the DOE to update the NWTRB on Program and Project plans, design, scientific and materials testing, multiple lines of evidence, and uncertainty analyses. The DOE also provided responses to specific NWTRB questions on performance assessment, an update on the Waste Package Performance Peer Review, and an update on the fluid inclusion studies being done by the DOE, the University of Nevada, and the State of Nevada.

On June 11, 2001, the Board sent the DOE a letter commenting on the Ad Hoc Panel discussion of multiple lines of evidence, noting that the Board and DOE agreed that some multiple lines of evidence could increase confidence in the performance-based projections of system performance ([159350] Cohon 2001). They stated that the more lines of evidence that can be derived independently of performance assessment, the more they could serve as a check on the conclusions of the performance assessment. The DOE's technical basis for Site Recommendation would be strengthened by extensive use of multiple lines of evidence.

A Joint Panel meeting was held on June 20-21, 2001, to discuss the DOE's SSPA Volumes 1 and 2 ([155950] BSC 2001, [154659] BSC 2001). The analyses in the SSPA focused on three of the NWTRB's key concerns: the treatment of uncertainty, a comparison of a lower- and higher-temperature operating modes, and the development of multiple lines of evidence. In addition, the DOE provided an update to the corrosion testing and modeling program to address the NWTRB's fourth key area of concern.

On July 17, 2001, the Board sent the DOE a letter on their May 8-9, 2001, meeting ([156890] Cohon 2001), noting that the Board is encouraged by DOE's work to quantify uncertainties and conservatisms in its performance assessment. The Board is concerned that some sources of uncertainty have been dismissed prematurely, and that the criteria for including some variables and not other is unclear. They also noted their continuing concern about the validity of some of the process models for corrosion processes. They questions DOE's approach of taking a single general design and comparing its performance and associated uncertainties when it is operated in a higher-temperature operating mode and a selected lower-temperature operating mode. The Board was encouraged by the DOE's commitment to develop multiple lines of evidence and specifically called on the use of insights from natural analogues.

On July 19-20, 2001, the NWTRB held an international workshop on long-term extrapolation of passive behavior of and the corrosion resistance of the WP materials. The workshop was designed to provide the Board with diverse opinions of highly qualified experts on the issue of extrapolating corrosions rates over long periods of time, which is one of the Board's key concerns.

A full Board meeting was held on September 10-12, 2001, to cover issues related to the technical and regulatory evaluations of the Yucca Mountain site. Discussion topics included standards and regulations that apply to this site, the DOE's preliminary evaluation of site suitability, and the plans for addressing NRC's KTIs. The DOE also provided updates on scientific and materials testing activities. Representatives of the State of Nevada and Nye County discussed the status of their technical work on evaluating the Yucca Mountain site.

2.5 PLANNED STUDIES NO LONGER NECESSARY

During this reporting period, the studies and activities were conducted in accordance with the Project baseline scope and schedule for Fiscal Year 2001. No planned studies were eliminated during the reporting period. More detail regarding how Project activities have evolved over time can be found in Revision 4 of the *Documentation of Program Change* (in progress).

2.6 DECISION POINTS REACHED

The key decision point reached during this reporting period was the initiation of the site recommendation consideration process, as required by Section 114 of the NWPA [101681]. As reported in Section 2.1, this process began on May 7, 2001, with the DOE announcing ([155009] 66 FR 23013) the initiation of a public comment period on the Secretary of Energy's consideration of the Yucca Mountain site for recommendation as a geologic repository. This announcement was accompanied by the issuance of various program documents and followed by the initiation of public hearings on September 5, 2001.

2.7 MODIFICATIONS TO SCHEDULES

The most significant modification to the Program's schedule during this reporting period was the deferral of a decision regarding a potential site recommendation to the President. This milestone, which was planned to be completed by July 2001, if the site was suitable, was deferred to early 2002 to allow further enhancement to the technical basis for a potential site recommendation. This enhancement included additional sensitivity analyses to evaluate the lower end of the thermal range for a flexible repository design concept. Additional consideration of uncertainties was also included in the technical basis.

The DOE is currently evaluating the schedule for submittal of the LA to the NRC, if the site is recommended and approved. The evaluation is considering the latest requirements of NRC's 10 CFR Part 63 ([156671] 66 FR 55732), recent interactions with the NRC, and the budgetary constraints from Congressional appropriations.

SECTION 3 – SITE CHARACTERIZATION

This section summarizes progress on selected site characterization activities for this reporting period.

3.1 GEOLOGIC INVESTIGATIONS

Geologic investigation work focused on updating model reports that support the Integrated Site Model, natural analogue studies to improve confidence in conceptual models, and field investigations to document the characteristics of excavation-induced fractures and to evaluate the role of faults as hydrogeologic features.

3.1.1 Integrated Site Model

The Integrated Site Model provides a three-dimensional portrayal of site geologic features and includes the Geologic Framework Model, the Rock Properties Model, and the Mineralogic Model. A fracture model was added during the reporting period to provide a consistent portrayal of fracture information for use in process models. The NRC has acknowledged that the Geologic Framework Model is an adequate tool for various site-scale analyses ([135621] NRC 1999, p. 125) and that they intend to use the model to conduct independent analyses of various DOE models that incorporate the Geologic Framework Model.

3.1.2 Natural Analogues

Natural analogues offer one of the multiple lines of evidence that support the understanding of conceptual models and provide a means, independent from TSPA, to build confidence in the ability of the Yucca Mountain site to isolate waste for thousands of years.

Natural and anthropogenic analogue studies continued during the second half of FY 2001 to corroborate the model processes that operate at scales too large to measure by laboratory and field-scale experiments. Analogues were also used to demonstrate that modeling codes represent processes correctly. Highlights of a few of the studies related to UZ transport are presented below:

Seepage–Evaluation of measured seepage in caves at Altamira, Spain, and Kartchner Caverns, Arizona, indicated that less than 2 percent of the available moisture became seepage (SSPA Vol. 1 [155950], BSC 2001, Section 4.3.1.7). Additional examples have been found since the SSPA Vol. 1 was issued. These new examples showed that a small percentage of infiltration becomes seepage in caves located in areas with moderate (Carlsbad, New Mexico) to very high precipitation rates (Ajanta, India) ([151957] Stuckless 2000). These examples indicate that most infiltration does not become seepage, and the natural analogues demonstrate that much of the seepage that does occur stays on the roof and walls rather than dripping. Furthermore, if relative humidity is kept below 100 percent through ventilation, seepage of liquid water is reduced or completely suppressed (SSPA Vol. 1, Section 4.3.1.7).

Unsaturated Zone Flow and Transport–As described in the SSPA Vol. 1, analyses of a few water samples from Peña Blanca, Mexico, showed a rapid decline in uranium concentration with increased distance from the ore deposit ([155950] BSC 2001, Section 11.3.4.8.1).

The large-scale aquifer pumping and infiltration test was modeled using TOUGH2 to simulate the highly transient water infiltration, ponded-water conditions, and conservative selenium (^{75}Se) tracer transport in the fractured basalt and sedimentary interbeds at the site. Six ponded-water hydrographs measured during the infiltration test were used during calibration with ITOUGH2 to estimate six parameters that controlled unsaturated flow in the fractured basalt and dense clay sedimentary interbed underlying the basalt flow.

Successful calibration of the flow model increased confidence in the dual-permeability approach used to represent the fracture and matrix continua of the basalt in simulation of transient unsaturated flow.

Thermally Coupled Processes–A literature review focused on the relevance of geothermal analogues to THC processes at Yucca Mountain. Dozens of geothermal fields were surveyed to address processes such as advective heating, conductive heating, fracture-dominated fluid flow, chemical transport, boiling, dry-out, condensation, mineral dissolution, and mineral alteration and precipitation. This review indicated that only a small portion of the fracture volume needs to be sealed to retard fluid flow effectively in low permeability rocks (such as the welded ash flow tuffs at Yucca Mountain) in which fluid flow is controlled by fractures. These geothermal analogue sites are under both saturated and unsaturated conditions and likely represent processes dominated by saturated flow processes. Our modeling that was used to simulate results of a laboratory experiment that showed fracture sealing does not indicate that mineral precipitation would affect flow around drifts greater than already produced by natural variability. Furthermore, fracturing and sealing occur episodically in geothermal systems. Sealing can occur over a period of days to years, depending on which processes trigger the precipitation of minerals. Rates and volumes of mineralization are controlled by mineral solubilities, reaction rate kinetics, and the flux and chemistry of circulating fluids. This survey noted the lowered rate and amount of expected change in an unsaturated repository compared to a saturated geothermal field.

Two studies focused on THC effects at the drift scale: one in an active geothermal system (Yellowstone National Park, Wyoming ([154503] Dobson et al. 2001 and [154547] Dobson et al. 2001) and one in a fossil hydrothermal system (Paiute Ridge, Nevada).

The Yellowstone and Paiute Ridge studies included detailed field observations of mineralogically induced changes to permeability caused by heat. Both studies acknowledged differences between the systems studied and Yucca Mountain, but also pointed out similarities, including the mineral alteration assemblages. These studies illustrated the differences in hydrothermal effects occurring in saturated and unsaturated systems, with effects in unsaturated tuffs altered by intrusion of the Papoose Lake sill being focused close to the contact between intrusion and host rock, whereas alteration in the saturated Yellowstone system was more pervasive and episodic.

3.1.3 Geologic Field Investigations

Geologic field investigations during the reporting period focused on characterization of excavation-induced fractures and hydrogeological features of faults that could affect groundwater flow.

Excavation-Induced Fractures–Because previously collected fracture data did not distinguish between natural and excavation-induced fractures, a study was undertaken, at the request of the NRC, to observe and document excavation-induced fractures. Fractures in the stratigraphic units that comprise the potential repository horizon were studied in the ESF; ECRB Cross Drift; Alcoves #2, #5, #6, and #8; and Niches 1 through 5 (Figure 3-1), where all three excavation methods (TBM, alpine miner, and drill-and-blast) had been used. In general, the impact of excavation on the formation of fractures was minimal and, therefore, excavation-induced fractures of significant size are rare in the underground excavations at Yucca Mountain. However, study results indicated that some general correlation existed between excavation-induced fractures and the construction method. TBM-induced fractures generally were found to penetrate only a few centimeters into the tunnel wall. The only area of the excavations that display significant TBM-induced fractures is in the ECRB Cross Drift between stations 15+50 and 16+50. Alpine miner-induced fractures were observed to penetrate more deeply, from a few centimeters to tens of centimeters from the excavation surface. Fractured induced by the drill-and-blast methods penetrated

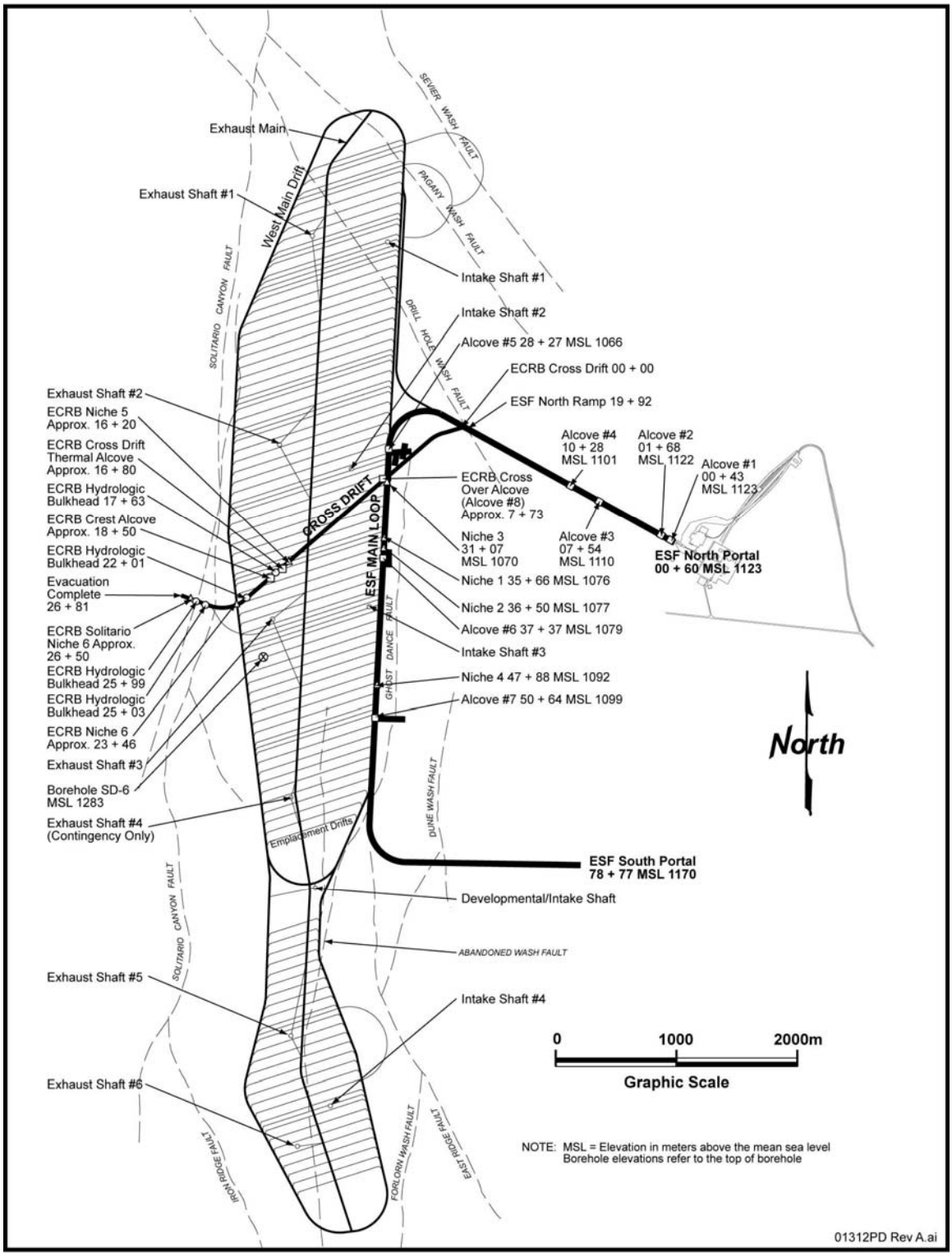


Figure 3-1. Layout of Potential Repository Showing the ESF Main Loop, the ECRB Cross Drift, and the Test Alcoves and Niches

most deeply, consistently extending tens of centimeters from the excavation surface. The information about excavation-induced fractures addresses a DOE-NRC agreement item (SDS 3.04) related to the Structural Deformation and Seismicity KTI ([154287] Gardner 2000).

Geotechnical Investigations for the Waste Handling Building–Geotechnical investigations for design of the proposed Waste Handling Building have been completed. All field data have been compiled and geotechnical analyses have been performed, including ring density calculations, laboratory tests, and interpretation of borehole logs. A report is in preparation. Study results indicate that the site consists of faulted, gently dipping pyroclastic and ash-fall volcanics overlain by interfingered colluvium and alluvium. Beneath the North Portal pad, the gravelly soils are generally well cemented with pedogenic calcium carbonate. Farther east and away from the base of the Exile Hill slope, the soils become somewhat finer, and are generally uncemented. Data from drill holes indicate that the soils in the vicinity of the proposed Waste Handling Building are underlain by rocks of the pre-Rainier Mesa bedded tuffs, Comb Peak Ignimbrite (Tuff "X"), and Tiva Canyon Tuff. Nine faults underlie the site, one of which is projected to have significant stratigraphic offset–approximately 100 m. The fault is down to the northeast and creates a graben with a northwest striking, down to the southwest normal fault, just northeast of the pad. The graben formed by these two faults has almost 100 m of non-welded tuff overlying the densely welded Tiva Canyon tuff. None of the faults are believed to offset any of the unconsolidated soils.

Hydrological Features of Faults–Faults vary both laterally and vertically in their physical characteristics and hydrogeologic properties. A recent study concluded that faults at Yucca Mountain are hydrogeologic features that could affect groundwater flow by acting as barriers, conduits, and combined conduit/barriers, or by juxtaposing strata with different hydrologic characteristics ([156880] Dickerson 2001). In general, intrablock faults (faults within the potential repository block) may increase the potential for fluid flow by increasing bulk intrablock fracture porosity, whereas block-bounding faults, which vary more widely in their fault characteristics, may act locally to enhance, impede, or channelize fluid flow. Fault orientation could affect the hydrologic characteristics of faults by creating changes in the hydromechanical properties of rocks at bends in the fault trace. Faults at Yucca Mountain increase in both size and number toward the south, which tends to increase the potential for fluid flow. However, nonwelded tuffs, which may act to retard fluid flow, decrease in thickness to the south.

3.2 NEAR-FIELD ENVIRONMENT

Near-field environment work focused on preparation of Sections 4.3.5 through 4.3.7 of the SSPA Vol. 1 ([155950] BSC 2001). These sections address the coupled effects of TH, THC, and THM processes on seepage into emplacement drifts. Analysis and modeling of the Drift Scale Test, needed to validate conceptual models of coupled processes, continued during this period.

3.2.1 Near-Field Environment

SSPA Vol. 1 ([155950] BSC 2001) was issued in July 2001. This report was prepared to supplement information contained in the S&ER ([153849] DOE 2001) to support the consideration of the possible site recommendation. In particular, this supplemental report addresses several specific aspects of the existing uncertainties related to the performance of a potential Yucca Mountain repository, including parameter bounds, conceptual models, assumptions, and repository operating modes for a range of temperatures.

Section 4.3.5 of the SSPA Vol. 1 ([155950] BSC 2001) summarized the modeling and uncertainty studies performed to predict how decay heat from emplaced waste would affect the magnitude and spatial distribution of percolation flux reaching the emplacement drifts, and, in turn, the potential seepage into drifts. Model results showed that wall temperatures above the boiling temperature of water limit the amount of water flow that reached the emplacement drift. That is, for the higher-temperature repository,

a dry superheated zone would develop around the drifts and possibly eliminate seepage into the drifts. The superheated zone would persist for a limited time and rewetting of the drift would occur as the system cools.

Thermal effects on seepage would be insignificant when the temperature is below boiling. Based on the results of the process models presented, the TSPA model ([148384] CRWMS M&O 2000) was modified to make it more realistic during the thermal period. The modification removed the assumption that the typical percolation flux was the same as that at 5 m above the drift, and removed the assumption to neglect the effect of the dry, superheated zone around the drifts as a vaporization barrier for seepage. However, the recommended extension to the TSPA model may still be conservative. Instead of adopting the results from the numerical models that no seepage occurs during the thermal period under expected repository conditions, the TSPA uses the analytical model that results in penetration of episodic pulses through superheated rock. Such penetration could produce seepage under some conditions.

Section 4.3.6 of SSPA Vol. 1 ([155950] BSC 2001) evaluated the THC effects on seepage and on the chemistry of water and gas that might enter drifts for a range of operating temperatures. Model results indicated that mineral precipitation would not affect flow around the drifts to a degree greater than that already produced by the natural variability in hydrologic properties. The models have also reproduced the results of a laboratory experiment that showed fracture sealing within several days. Predictions also indicated a restricted range in the chemistry of potential seepage water.

In Section 4.3.7 of SSPA Vol. 1 ([155950] BSC 2001), two alternative conceptual and numerical models (the distinct-element model and the fully-coupled continua model) were used to study the impact of coupled THM processes on potential seepage into drifts. Permeability changes predicted by the models (in the elastic regions apart from the immediate neighborhood of the drift that was part of the Drift Degradation Analysis) (SSPA Vol. 1, Section 4.3.4) were about one order of magnitude, which was within the range of the ambient seepage model. Different conceptualizations produced opposite modeled effects, however, this range of uncertainty in permeability was captured in an analysis of effect of drift degradation on potential seepage described in Section 4.3.4 of the SSPA Vol. 1. Consequently, percolation flux values and flux distribution above the drift were not significantly affected by THM effects.

3.2.2 Thermal Tests

Large-scale, field thermal tests are integral parts of the program to characterize Yucca Mountain. The thermal tests validate conceptual models of coupled thermal, mechanical, hydrological, and/or chemical processes that result from the heat produced by the decaying radioactive waste.

The Drift Scale Test, which is in its fourth year of heating, continued with a collection of thermal, hydrological, chemical, and mechanical response data. In June 2001, a total of eight new rock samples were obtained by side-drilling three locations within three boreholes mainly to investigate the mineralogic/petrologic response to the thermal-hydrological environment near the boiling zone. Analyses of similar samples collected last fall were presented at the Thermal Test Workshop (June 7, 2001) in Las Vegas, Nevada. Chemical compositions of minerals in rock samples obtained from these three boreholes were analyzed, semi-quantitatively, by energy-dispersive x-ray spectroscopy. The three products observed so far were tentatively identified as amorphous silica, a calcium sulfate phase (gypsum or anhydrite), and a calcium-rich phase that is probably calcite. The significance of these observed minerals deposited during the Drift Scale Test is that they provide an opportunity to test the predictive accuracy of the geochemical models. The models simulate the coupled thermal-hydrological-chemical processes and make specific predictions about the minerals that will be deposited. If the composition of the mineral deposits predicted by the simulations match the composition of the observed mineral deposits,

the adequacy of the models is validated. The silica deposits exhibited considerable textural heterogeneity, perhaps because some were deposited when the collection site was in the condensation zone, whereas others were deposited when boiling-zone dryout conditions were reached. The source of sulfate is likely to be from the sulfate dissolved in the pore water, which deposits as calcium sulfate when the pore water evaporates.

During this reporting period, water was sampled from hydrology boreholes on three different occasions. Sampling was conducted in April, June, and August from several zones having temperatures above 110°C. Some of these samples contained higher total dissolved solids, lower pH, and higher concentrations of fluoride than samples collected at lower temperatures. In these high temperature regions of the rock, water is present only as superheated vapor; liquid water is obtained during the sample cooling process. The compositions of the condensed steam samples that are high in fluoride suggest dissolved hydrogen fluoride gas in the aqueous phase. Further testing and analyses are being performed to determine if the water samples were contaminated with fluoride from the Teflon™ tubing and/or the fluoroelastomer packer materials that were installed in 1997, or if the source of fluoride was the host rock. If the source of the acidic water is determined to be the host rock, the acidic water could impact repository performance by accelerating the degradation rate of the WP and drip shield.

During a cleaning and reinstallation of the Drift Scale Test bulkhead windows, loose rock was observed at several locations above the welded wire fabric attached to the roof of the heated drift. Despite the appearance of inelastic deformation, on-site personnel with much experience assessing ground support systems believe the welded wire fabric and rockbolts remain competent and will continue to support the existing loose rock in the observed zones. In addition, no evidence was found of failed components or deep fractures. Pieces of rock that were held by the welded wire fabric varied in diameter from about 5 cm (silver dollar size) to about 20 cm (dinner plate size).

An effort was made in July to measure the amount of heat and water vapor escaping the heated drift, through the bulkhead, into the cooler ventilated areas. Thirty-nine sensors measuring temperature and relative humidity were hung from wires at various locations between the bulkhead and the ventilation ducts, about a distance of 10 m. Preliminary analyses indicated that these heat loss measurements showed that the amount of energy lost through the bulkhead was less than the model predictions. Scientists believe that the attempted measurement was flawed for the following reasons:

- The data acquisition system was not set to record often enough to capture the changing humidity conditions.

- A thermally driven convection cell formed from cool air traveling along the floor toward the bulkhead and warm air traveling along the roof away from the bulkhead. This convection cell overwhelmed the small air-circulation fans, such that a thorough mixing of the air (to incorporate a representative amount of water vapor) was not possible.

Another attempt to characterize the vapor and heat loss will be made later this fall, using an improved data acquisition system and better control of the airflow around the sensors.

A white paper, entitled “Heat and Mass Flow through the Bulkhead in the Drift Scale Test” (attachment to [156745] Dobson 2001), was transmitted to the NRC to satisfy an agreement (TEF 2.1) reached between DOE and the NRC at the January 2001 Technical Exchange on Thermal Effects on Flow. The paper included discussion of measurements, model simulations, and analyses. The paper argued that the favorable comparison of modeled results and observations for both temperatures and bulk moisture redistribution demonstrated that all the major components of the TH processes were included in the process models (including vapor loss through the bulkhead). Therefore, the objectives of acquiring a

more in-depth understanding of the coupled processes and validating the conceptual TH processes at a drift scale are being met in the Drift Scale Test.

Work continued on two data packages for Drift-Scale Test in Alcove #5 (Figure 3-1) water samples, one package for uranium-isotope data and one for strontium-isotope data. The data have been documented and compiled in tabular form. However, these data packages are incomplete because of lack of a few data-collection reports (to be obtained from the Sample Management Facility) or chain-of-custody information. Efforts to obtain the missing information continued so that the data can be submitted to the technical database early in the next reporting period.

Strontium and uranium isotopic compositions in water samples collected from the Drift Scale Test continued to show strong similarity to ambient pore water, indicating that heating has had little impact on the isotopic composition of these elements in water. These data reduce the uncertainty in predictions of the conceptual models of water-rock interactions and of the contamination from engineered materials in the test block.

3.3 SITE UNSATURATED ZONE FLOW AND TRANSPORT

Site UZ flow and transport studies focused on improving the understanding of infiltration, percolation, and seepage in the ESF, as well as confirming environmental tracer (^{36}Cl and ^{3}H) results that seem to indicate the existence of fast pathways between the surface and the repository horizon. Other geochemistry investigations examined the calcite abundance, origin of secondary calcite and silica deposits, pore-water compositions, and fluid inclusions in secondary minerals as indicators of past groundwater movement ([154773] Whelan et al. 2001). Along the ECRB Cross Drift, studies were conducted for seepage and systematic hydrological characterization in the lower lithophysal zone of the Topopah Spring welded tuff unit (TSw); moisture monitoring behind sealed bulkheads; and drift-to-drift migration, seepage, and matrix diffusion processes. The Busted Butte UZ transport test continued to quantify the effects of expected hydrogeologic conditions in the Calico Hills nonwelded tuff below the potential Yucca Mountain repository horizon.

3.3.1 Enhanced Characterization of the Repository Block Cross Drift

Testing in the ECRB Cross Drift during the reporting period focused on characterizing moisture movement and included seepage rate tests and relative humidity and evaporation testing and monitoring. The drift-to-drift test is being conducted at the specific location where the cross drift crosses over the ESF Main Drift. Data from the series of seepage rate threshold tests were compared to assess the effects of drift ventilation and fluid storage in suppressing seepage observations. The early seepage test results at Niche 2 (Figure 3-1) were based on short-duration releases of pulses above the niche. More recent tests at Niche 3 and Niche 4 (Figure 3-1) were conducted for long durations in sealed niche conditions. The comparative analysis indicated that seepage thresholds exist under the conditions of both short-duration tests and long-duration tests (with seepage rates reaching quasi-steady-state conditions in long-duration tests). The short duration tests, originally designed to simulate the arrival of episodic percolation events through fast-flow paths into ventilated drifts, did not provide the data sets needed for the seepage calibration and other performance assessment models, which emphasize steady-state conditions in sealed drifts under post-emplacement conditions.

Niche Seepage Studies–Most of the work at the other niches in the ESF was completed prior to this reporting period. Analysis of results was ongoing and reported in Section 5 as it was incorporated into the UZ Process Models. Boreholes at Niche 5 at ECRB Cross Drift station 1620 in the lower lithophysal zone have higher air-permeability values than of niches in the middle nonlithophysal zone of TSw. The relative changes in permeability before and after niche excavation are smaller in the lower lithophysal

zone than in the middle nonlithophysal zone. Initial seepage testing at Niche 5 at ECRB Cross Drift station 1620 was begun in February 2001 but was halted in April to allow for the construction of two slots within the niche. No seepage or wetting was observed during the short duration of this test. Construction activities were terminated after creating a 2- to 3-m long irregular-shaped excavation in the left wall of the niche. The barometric pressure, temperature, and relative humidity of the air within Niche 5 at ECRB Cross Drift station 1620 were measured from July through August 2001. In addition, the rate that water evaporated from a free surface was measured. Monitoring took place with the bulkhead doors at the entrance to the niche closed and sealed.

Alcove #8/Niche 3 Test–In the drift-to-drift test, designed to evaluate migration and seepage from the ECRB Crossover Alcove #8 (Figure 3-1) into Niche 3 in the ESF Main Drift, application of water to four trench compartments along a fault near the end of Alcove #8 continued. The liquid release began along the fault on March 6, 2001. The quasi-steady intake rates ranged from approximately 25 liters per day to approximately 80 liters per day for the four trenches. The advancing edge of the wetting front was first detected on April 9, 2001, along a borehole above Niche 3. The flow path of the advancing wetting front was shown to be fairly localized. Seepage was first observed on the niche ceiling on April 10, 2001, with seepage rates climbing to near-steady values in the next four to eight weeks. The Alcove #8/Niche 3 test has provided preliminary observations of how water flows through a fault located within fractured, welded units of the Topopah Spring Tuff. Current observations include travel velocities within the fault and some indications of the magnitude of wetted-plume dispersion following localized releases in the fault. The wetting front travel time over a distance of 20 m is of the same order of magnitude as the travel time over 30 m observed in the Alcove #1 infiltration test conducted in the Tiva Canyon Tuff (see Progress Report Number 23 ([155982] DOE 2001, Section 3.3.1). The plume is fairly localized as indicated by measurements from borehole sensors and from observations of seepage exit points on the Niche 3 ceiling.

Systematic Hydrological Characterization–With the automatic data collection setup and the injection and seepage collection equipment mounted on mobile rail flatbeds, the systematic hydrological characterization system can test many borehole zones if tunnel access is readily available. Air-permeability and seepage tests were conducted along multiple zones in three 20-m long boreholes drilled into the crown of the ECRB Cross Drift. The field data have been systematically analyzed to gain knowledge of the effects of heterogeneity and insights about governing processes. Drift ceiling seepage observations indicated that the participation of the lithophysal cavities in liquid flow is small. Based on measurements of injection, seepage, and evaporation-rate data, upper bounds of seepage loss to evaporation were established. Uncertainty notwithstanding, evaporation did not account for all the differences between injected water and collected seepage water. The systematic hydrological characterization concluded that a seepage threshold exists in the lower lithophysal zone of the TSw. The data for one of the boreholes, ECRB SYSTB LA#2, have been used for the development, calibration, and validation of the Seepage Calibration Model.

ECRB Cross Drift Bulkhead and Moisture-Monitoring Studies–Moisture monitoring between the bulkheads in the ECRB Cross Drift continued during the reporting period. Previously, the bulkheads were opened from January 22, 2001, to January 25, 2001, and observations were made with respect to the presence of moisture (see Progress Report No. 24, Section 3.3.2; in progress, see Appendix B). Temperature and relative humidity measurements were made behind the bulkheads from January 22, 2001, to July 9, 2001.

On April 6, 2001, power to the TBM was cut off during routine maintenance of the tunnel electrical system. When maintenance was completed, power to the TBM and to the dataloggers behind the second and third bulkheads was not restored. Temperatures began falling behind the second and third bulkheads and the temperature gradient toward the end of the ECRB Cross Drift diminished.

The continued power loss to the TBM resulted in a decreased temperature gradient within the tunnel. The appearance of moisture behind the third bulkhead and the smaller amount of moisture between the second and third bulkhead indicates that as the temperature gradient decreased, observable moisture tended to move toward the TBM.

3.3.2 Field-Scale Busted Butte UZ Transport Test Facility

The Busted Butte UZ transport test was designed to address solute and colloid movement through tuff layers that underlie the potential repository horizon. The test involved field-scale tracer injection tests, laboratory analysis of pads collecting tracer from the field, and computational modeling to test the conceptual models being used for the YMP.

Field and Tracer Results–Phase 2 injection was terminated on October 30, 2000. During January and February 2001, five cores were taken around and under three of the injection holes. The core locations were selected to examine near-injection transport at each of the injection rates. Dissolved species of the metals Ni, Co, and Mn were used as surrogates for the dissolved radionuclides of Am, Pu, Tc, and Np under the Busted Butte test conditions. Except for lithium, metals were not detected at the collection pads.

Samples from cores below the highest-injection-rate boreholes (50 ml/hr) have been analyzed. This injection rate was far higher than any expected ambient flow and thus should have produced travel distances greater than those expected under ambient conditions. Preliminary results from the rock-extraction studies for the 830 day tracer test showed that reactive metals (Ni, Co, and Mn) were restricted to the environment adjacent to the injectors (tenths of meters), while Li and Br ions migrated to the pad collection boreholes (meters). Cobalt traveled approximately 0.3 m-below the injector, while Ni concentrations elevated above background have been observed approximately 0.15-m below the injector.

Colloid Transport–To assess colloid transport in the UZ, polystyrene microspheres (44-nm and 190-nm diameter) were injected as part of the tracer mixture, as surrogate colloids. Qualitative assessment of in situ microsphere transport in the cores taken around and below injection boreholes, showed transport of approximately 0.21-m below the 50-ml/hr injectors over the 730-day injection period. From these rock analyses, it was not possible to distinguish between the two sizes of microspheres injected.

In addition, microsphere migration was analyzed in the laboratory in saturated cores. In the laboratory a mixture of microspheres and LiBr was injected into core samples for all three units present at Busted Butte (Tac, Tptpv1, Tptpv2). The percent of mass recovered for 190-nm microspheres within the laboratory Tac cores varied as a function of ionic strength of the LiBr solution, with 21 percent recovered at 0.01 M LiBr and 36 percent at 0 M. In contrast, 44-nm microspheres had up to 82 percent recovery in the same material, which indicated that a larger fraction of the smaller colloids migrate through this material.

A new model developed to predict colloid transport under the transport test conditions allows four different physical mechanisms for colloid transport. Based on very-high resolution characterization of Tac pore space, this model predicted a travel distance of less than 50 m after 450 years for a 50 percent saturated system. The simulated conditions represented the physical Tac system as accurately as possible. Saturation was slightly higher (50 percent instead of estimated 35 percent in situ pre-UZ transport test), which would increase potential transport predictions over a lower saturation condition.

Based on laboratory and field investigation and model predictions, colloid transport in unsaturated conditions was much more limited than in saturated conditions. Long travel distances for any significant volume of colloids through the UZ is unlikely for colloids larger then 200 nm, but there is not enough information to evaluate the transport of smaller colloids.

Role of Structure–Prior to incorporating stratigraphic detail from the excavation, the Phase 2 simulation results matched well the general character of the tracer distribution well. Representation was better for near-field collection boreholes and for boreholes in the Tac. In the Tac, injection and collection boreholes generally resided within the same unit. More accurate geologic representation in the computational grids, based on incorporating basic stratigraphic information and additional information from cores, produced improved predictions.

Evidence indicated that flow and transport in the nonwelded to moderately welded tuffs evaluated in the UZ transport test (Tac, Tptpv1, Tptpv2), are dominated by matrix flow. Fractures appeared to play little, if any, role in enhancing flow and transport, based on fluorescein observations from Phase 1, and comparing pad tracer data and simulations in Phase 2. However, deviation between simulation and pad tracer data in Phase 2 suggested that faults, fractures, and material boundaries might have significant roles as barriers to fluid and contaminant movement.

Block Laboratory Experiments–The Atomic Energy of Canada, Ltd. laboratory transport testing is using the smaller (30-cm [12-in.]) block from Busted Butte and the following tracers/isotopes: Na-fluorescein, ^{3}H, ^{22}Na, ^{60}Co, ^{99}Tc, ^{137}Cs, and ^{237}Np. The results obtained from elution profiles showed that transport of Tc (injected as an anionic TcO_4^- species) was approximately 15 percent faster relative to an ideal non-reactive tracer, $^{3}H_2O$, but that neptunium (injected as the neptunyl ion NpO_2^+) was retarded by a factor of approximately 3. In *Batch Sorption Results for Neptunium Transport Through Yucca Mountain Tuffs* ([101023] Triay et al. 1996), Triay et al. reported the results of column experiments with crushed tuff and showed Np breakthrough curves indicating retardation coefficients always greater than 1 and ranging up to approximately 4, depending on rock type. The Atomic Energy of Canada, Ltd. findings fall within this range. Retardation of ^{22}Na, ^{60}Co, and ^{137}Cs by the geological material was higher than for Np. Post-experiment radiometric analysis of the tuff, which is currently underway, shows that the order of retardation is $^{22}Na < ^{137}Cs < ^{60}Co$. This agrees qualitatively with the experimentally determined static batch sorption coefficients for these radioisotopes. Tracer breakthrough has not yet occurred in the larger (1 m^3) block test.

3.3.3 ESF Alcove and Niche Studies

Studies in ESF niches and alcoves focused on validation of the results of the chlorine-36 (^{36}Cl) study, and the origin of calcite-silica deposits.

Chlorine-36 Validation Study–Participants in the ^{36}Cl validation study met on April 23, 2001, to discuss progress made in developing a standard leaching protocol using a reference sample of tuff. Two leaching methods were compared, and release curves from the two methods were in good agreement. Cl/Br ratios for one set of leachates suggest leaching of increasing amounts of construction water as a function of time, a phenomenon that has not yet been explained. The $^{36}Cl/Cl$ analyses from the same set of leachates showed decreasing ratios as a function of leach time, as would be expected if continued leaching liberated an increasing quantity of rock chloride. Comparison of both active and passive leach data led to agreement on a standard protocol involving passive leaching of crushed rock for 24 hours.

At a meeting convened on July 18, 2001, by the DOE-YMSCO, the status and path forward for the ^{36}Cl validation project was reviewed. The agreed-upon path forward includes selection and independent re-analysis of samples for Cl, Br, and SO_4 concentrations. Analytical results will be evaluated and reviewed to determine whether the two sets of ^{36}Cl values are consistent and provide the same information with respect to fast water-flow pathways from the land surface to the proposed repository horizon. The first suite of samples prepared and distributed for leaching and isotopic analysis will be from the area of the Sundance fault in the ESF where previous results indicated that approximately 50 percent of the samples taken had significantly elevated ^{36}Cl contents. The preliminary results from this suite of samples will be summarized in the next Progress Report.

Origin of Secondary Calcite and Silica Deposits and Fluid Inclusions–Studies of the origin of secondary calcite and silica deposits continued to provide insights about past and present liquid-water flow through the UZ. The sporadic distribution of secondary mineral deposits on no more than 6 percent of fractures (on footwalls) and in 1 to 42 percent of lithophysal cavities (on floors) was consistent with simulations of fracture flow processes in an unsaturated-zone setting ([154773] Whelan et al. 2001). The distribution and restriction of deposits to footwalls and floors were inconsistent with a rise in the water table, or even localized hydraulic saturation, which would indiscriminately and universally mineralize all fractures and cavities in the regions of flooding. Data from fluid inclusion studies indicated that the rock mass probably has been unsaturated throughout secondary mineral deposition and at near-ambient temperatures for at least the last 2 million years, and possibly as much as 4 million years.

Project scientists continued analyses of fluid inclusions in secondary calcite deposited in the UZ at Yucca Mountain to help confirm major conclusions summarized during the last reporting period (see Progress Report No. 24; in progress, see Appendix B). The ages of the opal and chalcedony layers that overlay older calcite deposits containing fluid inclusions that were formed at elevated temperatures ([156889] Neymark et al. 2001) were determined by analysis of the $^{235}U/^{207}Pb$ ratios in fourteen sub-samples. The ages were found to range between 1.88 ±0.05 and 9.7 ±1.5 million years with most ages older than 6 to 8 million years. These data indicate that fluids with elevated temperatures have not been present in the UZ at Yucca Mountain since about 1.9 million years ago and most likely not since 6 to 8 million years ago. Discordant U-Pb isotope data for chalcedony sub-samples representing the massive silica stage in the formation of secondary-mineral coatings were interpreted using a model of the diffusive loss of uranium decay products. The model gave an age estimate for the time of chalcedony formation about 10 to 11 million years ago, which overlaps ages of clay minerals formed in tuffs below the water table at Yucca Mountain during the Timber Mountain thermal event.

3.3.4 Other Unsaturated Zone Field Investigations

Other UZ investigations included surface-based borehole monitoring and UZ geochemistry.

Monitoring at Surface-Based UZ Boreholes–Monitoring of in situ pneumatic pressure, temperature, and water potential continued throughout the reporting period in surface-based boreholes UE-25 UZ#5, UE-25 UZ#4, and USW NRG-7a despite earlier plans to discontinue monitoring on May 15, 2001. In a conference call between the DOE and the NRC held June 7, 2001, DOE informed the NRC that it intended to discontinue the monitoring. When NRC staff questioned whether water potential values in the boreholes had stabilized since publication of the monitoring data in 1996 and 1997, DOE agreed to continue the monitoring temporarily, evaluate the data, and report the results of that evaluation to the NRC. On October 11, 2001, the DOE and the NRC held an Appendix 7 meeting on unsaturated-zone testing in Las Vegas, Nevada, and discussed termination of UZ borehole monitoring. The DOE explained that over the last ten years the monitoring activities have provided all the data and information useful for UZ model development and that further monitoring would provide little, if any, new information. Consistent with prioritizing competing activities for the Project, the DOE has decided to terminate

borehole-monitoring activities. Plans now are to continue monitoring long enough (into December 2001) to achieve an orderly closeout of the activity, complete final calibrations of aboveground data systems, and ensure that no data are lost.

Temperature and pressure measurements from surface-based borehole UE-25 UZ#4 in Pagany Wash were used to estimate infiltration and percolation through the 12.1 m of alluvium resulting from the February 1998 El Niño precipitation and runoff events ([156881] LeCain and Kurzmack 2001). Temperature disruptions measured at borehole UZ#4 indicated that significant infiltration occurred into Pagany Wash during a short time period. Analytical and numerical infiltration flux estimates ranged from 700 to 1300 mm. Temperature and pressure disruptions at stations located in the vitric zone of the Tiva Canyon Tuff (24.5 meters deep) and the Yucca Mountain Tuff (35.2 meters deep) indicated deep percolation of some portion of the infiltration flux.

UZ Geochemistry–Isotopic compositions of core-water samples from boreholes USW SD-6 and USW WT-24 indicated that relatively young water has been introduced at depth ([156884] Yang 2001). Tritium, carbon, oxygen, and deuterium isotopic compositions all supported younger water at depth in the two boreholes. Peaks in tritium concentrations in pore-water samples, indicating young water, were observed near the basal vitrophyre of the Topopah Spring Tuff, at the bottom of the Calico Hills Formation, and at the top of the Prow Pass Tuff in both boreholes SD-6 and WT-24. Carbon-14 activities in pore-water samples from WT-24 also indicated younger water at the same stratigraphic locations. In both boreholes, oxygen-18 and deuterium data indicated younger water at the bottom of the Calico Hills Formation. The younger water at depth in boreholes SD-6 and WT-24 and occurring at the basal vitrophyre of the Topopah Spring Tuff and near the Calico Hills Formation/Prow Pass Tuff contact probably was derived from lateral, preferential flow through connected fractures (fast-flow paths). The source of the young water at borehole WT-24 probably was recharge from The Prow of Yucca Mountain to the north that flowed laterally southward through the highly fractured Topopah Spring welded unit. The source of the young water at borehole SD-6 was probably water flow from the Solitario Canyon fault to the west, which flowed laterally through the Topopah Spring welded unit and the Calico Hills Formation.

A published report describes the fundamental physical, isotopic, and geochronological aspects of secondary-mineral deposition in the UZ at Yucca Mountain ([156507] Paces et al. 2001). The published report superseded a YMP milestone report about ages and origins of secondary minerals in the ESF ([100171] Paces et al. 1996).

3.4 SITE SATURATED ZONE FLOW AND TRANSPORT

SZ work included compilation of borehole logs and geochemical analyses for major anions, major cations, trace elements, and the oxidation states of arsenic, selenium, and antimony for samples from the Nye County drill holes. At the Alluvial Testing Complex, hydraulic and tracer testing, and radionuclide transport testing in alluvium continued. Locations of the Nye County holes and the Alluvial Testing Complex are shown in Figure 3-2.

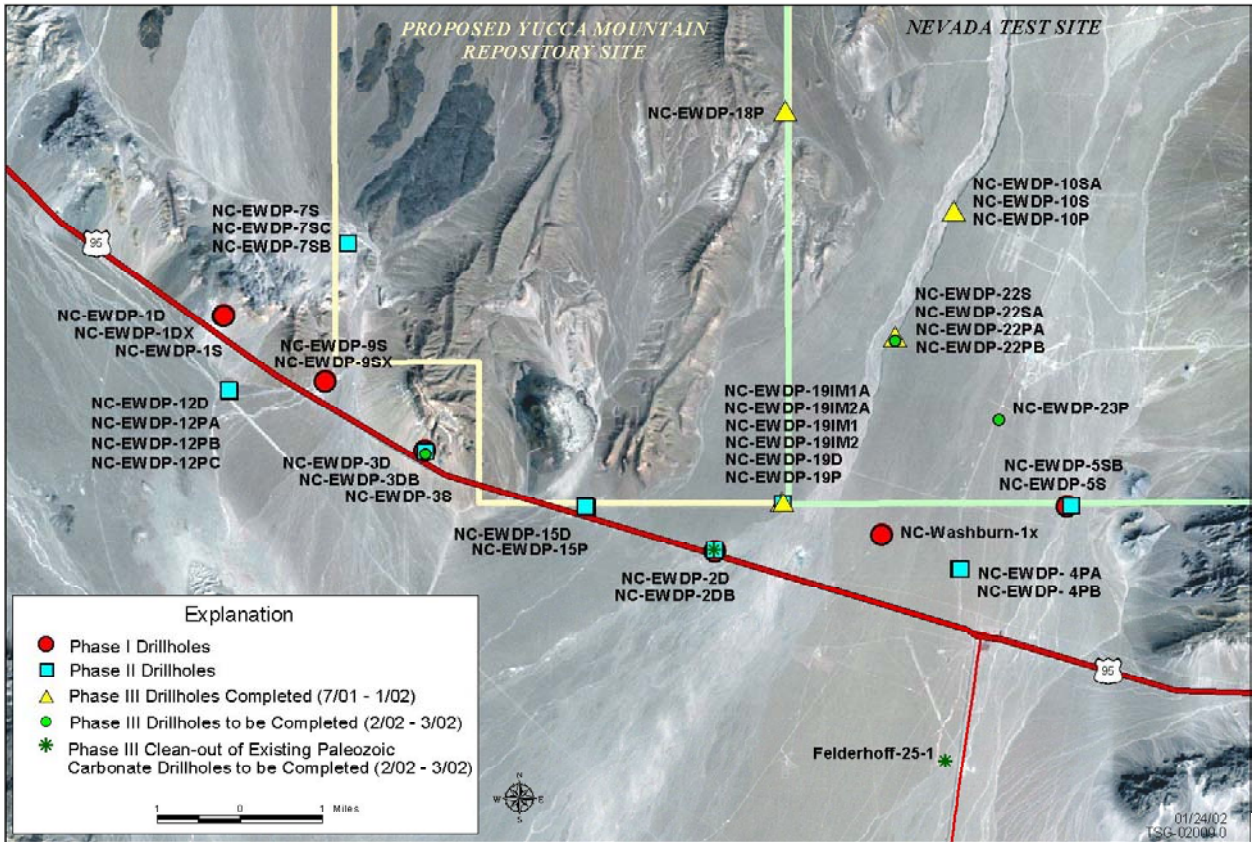


Figure 3-2. Map Showing Locations of Nye County Early Warning Drilling Program Wells

3.4.1 Nye County Early Warning Drilling Program

A data package titled "Interpretation of the Lithostratigraphy in Deep Boreholes NC-EWDP-7SC, NC-EWDP-19D1, NC-EWDP-2DB, and NC-EWDP-15D, Nye County Early Warning Drilling Program" is in preparation. The data represent the Project's initial examination and interpretation of the subsurface lithostratigraphy near the southernmost extent of Yucca Mountain and Fortymile Wash. The data indicate that in the vicinity of Highway 95, pyroclastic flow deposits commonly are inter-layered with very thick sequences of siltstone and claystone of Tertiary age. North of Highway 95, these intervals of siltstone and claystone pinch out and are replaced by pyroclastic fall deposits that typically separate major welded pyroclastic flow deposits within the central part of Yucca Mountain. Borehole NC-EWDP-2DB of the Phase II drilling currently represents the deepest penetration of subsurface strata, extending to a depth of 3,075 ft (937 m). Quartzite, dolomite, shale, and limestone were encountered between depths of 2,670 ft (814 m) and 3,075 ft (937 m) and are interpreted to be Paleozoic in age. Aside from borehole UE-25 P#1, drilled north of Busted Butte, NC-EWDP-2DB represents the only other borehole that has been drilled deep enough to encounter Paleozoic rocks within the Yucca Mountain area.

Three new geologic cross sections that extend across Fortymile Wash and southern Yucca Mountain were completed. These cross sections integrate borehole data from Nye County's Phase I and Phase II drilling, surface-based geophysics, and surface geologic mapping. Information derived from these cross sections is intended to aid in revising the site and regional hydrologic framework models and to help predict subsurface geology at future Nye County drill sites.

As represented in cross section Nye-2 within NC-EWDP-19D1, the Topopah Spring Tuff is 440 ft (134 m) thick and appears exceptionally uniform in physical properties. The unit is composed entirely of nonwelded zeolitic tuff and lacks zonal variations that typically aid in identifying the tuff ([154686] DTN: MO0007NYE02565.024; [154704] EDCON 2000). Significant differences in the thickness and welding characteristics of the Topopah Spring Tuff occur between NC-EWDP-2DB and NC-EWDP-19D1 (approximately 1 km apart) as well as between NC-EWDP-19D1 and boreholes to the north. These differences provide supporting information for the presence of the buried east-trending faults, such as the Highway 95 fault and other buried fault splays that are part of cross sections Nye-1 and Nye-2.

3.4.2 Alluvial Testing Complex

During the reporting period, the principal focus of activities at the Alluvial Testing Complex project was the interpretation of single-hole hydraulic tests and single-hole injection-pumpback tracer tests conducted in well NC-EWDP-19D1 from July 2000 through April 2001. The open-hole alluvium test data were analyzed using the Neuman unconfined aquifer analytic solution ([150321] Neuman 1975), which yielded a transmissivity value of 223 ft^2/day (21 m^2/day) for the interval between the water table at about 349 ft (106 m) and the alluvium tuff boundary at about 812 ft (247 m). Considering the 463 ft (141 m) thickness of the saturated alluvium to be from the water table to the top of the packer isolating the alluvium from the tuff units below, the resulting value of hydraulic conductivity was about 0.5 ft/day (0.15 m/day).

Following the open-hole test, four intervals were isolated in well NC-EWDP-19D1 and hydraulically tested individually to obtain an estimate of vertical heterogeneity in hydraulic properties, which will be used in the conceptual model of flow in the SZ down-gradient from Yucca Mountain. All of the screened-interval test results exhibited unconfined aquifer behavior. For this to happen, the entire saturated thickness of the alluvium from the water table to the bottom of the screened interval being tested must have been affected by each test. Except for the next to uppermost interval, which was strongly influenced by a clay layer, the tests in all the other intervals indicated a transmissivity of about 300 ft^2/day (27.9 m^2/day) for the total saturated thickness of the alluvium. Therefore, a hydraulic conductivity value representative of the entire saturated alluvium at well NC-EWDP-19D1 was calculated to be 0.7 ft/day (0.2 m/day), except for the clay layer. The clay layer exhibited a transmissivity of 7.5 ft^2/day (0.7 m^2/day) and a hydraulic conductivity of less than 0.23 ft/day (0.07 m/day).

After the isolated-interval hydraulic tests, single-hole injection-pumpback tracer tests were conducted in the uppermost screened interval of well NC-EWDP-19D1. In these tests, tracers (chemical tracers and/or microspheres) were injected into the well, followed by chase water, and the tracer plume was allowed to drift with the natural hydraulic gradient for a period of time. Subsequently, the well was pumped to pull the tracer plume back toward and into the test well. In the longest test, the tracer-plume drift phase lasted for 30 days and the pumpback phase lasted for 57 days. The breakthrough curves of the tracers concentrations measured in these single-well injection-pumpback tests were analyzed by two different methods to obtain preliminary estimates of specific flux. In the first method, it was assumed that the alluvium consisted of a homogeneous, isotropic, confined aquifer, which allowed estimates to also be obtained for effective porosity and longitudinal dispersivity. Preliminary results from this method indicated an effective porosity of 0.1, a longitudinal dispersivity of 5 m (16 ft), and a specific flux of 1.5 m/yr (4.9 ft/yr). In the second method, the peak, mean, and late arrival times of tracers were analyzed without assuming a homogeneous, isotropic, confined aquifer. Without these assumptions, it is not possible to obtain estimates of effective porosity and longitudinal dispersivity; but the specific flux can be determined as a function of the assumed effective porosity. The specific flux estimated from this method ranged from 1.3 to 9.4 m/yr (4.3 to 30.8 ft/yr), with the lower limit obtained from the peak tracer arrival analysis assuming a minimum effective porosity of 0.05, and the upper limit obtained from the late arrival analysis assuming a maximum effective porosity of 0.3.

3.4.3 Regional Groundwater-Flow Model

Several key efforts in the Death Valley regional flow system modeling project continued during the reporting period, with particular emphasis on database improvements, construction of the transient hydrogeologic framework model, refinements to the flow modeling system, and preparation of reports on the steady-state hydrogeologic framework and groundwater flow models. Additional spatial data sets processed into the transient hydrogeologic framework model included mapped outcrops, wells and boreholes, thrust-faults maps, cross sections, and other groundwater flow models (Oasis Valley, Silent Canyon caldera complex model, Nevada Test Site revised regional model, Frenchman Flat, and YMP site model GFM 3.1).

Two milestone documents related to regional-modeling databases were completed: an update on regional database integration and analysis and a year-end update on regional spatial data merge. Both milestone documents describe enhancement of the groundwater information system that includes lithologic and hydrostratigraphic data for 1,519 boreholes in the Death Valley region. The steady-state hydrogeologic framework model report (A Three-Dimensional Hydrogeologic Framework Model For Use With a Steady-State Numerical Ground-Water Flow Model of the Death Valley Regional Flow System, Nevada and California, in preparation) has been transmitted for USGS approval and DOE concurrence. The draft steady-state modeling report (A Three-Dimensional Numerical Model of Predevelopment Conditions in the Death Valley Regional Ground-Water Flow System, Nevada and California, in preparation) was revised in response to technical review comments and appropriate modifications to the flow model itself were made. The regional hydrostructural map (Potter et al. 2001, in preparation) was approved for publication by the USGS.

3.4.4 Other Saturated Zone Field Investigations

Other SZ field investigations included water-level monitoring, which is being transitioned to the University of Nevada Las Vegas, and studies of Pleistocene water-level fluctuations related to climatic changes.

Water-Level Monitoring–Several quarterly data packages for years 2000 and 2001 for manual and continuously recorded water-level measurements were processed through checker review and submitted to the Technical Data Management System. The water-level report for calendar year 1999 was revised to incorporate technical review comments and submitted for further processing. Additional work was focused on preparation of illustrations and tabular data for an open-file report on water levels during years 2000 and 2001. Transition of all water-level monitoring activities from the USGS to the University of Nevada Las Vegas Harry Reid Center was completed in September 2001.

Pleistocene Water-Level Fluctuations–An isotope geochemical study of paleodischarge deposits in the eastern Amargosa Desert indicated that the late-Pleistocene water table was 9 m higher than present based on subterranean calcite deposits associated with the separate regional carbonate-aquifer flow system discharging at Ash Meadows ([154724] Paces and Whelan 2001). A somewhat higher rise in the water table of about 17 m would be required to activate surface discharge at the Lathrop Wells diatomite deposit. A similar rise at the Crater Flat Wash deposit would not result in surface discharge. However, evidence for Pleistocene flowing springs and standing water was not as obvious at the Crater Flat Wash site.

Nevertheless, shallow water tables (less than 10 m) are likely to have supported abundant phreatophyte vegetation along with the development of eolian and capillary-fringe deposits. Therefore, Pleistocene water-table fluctuations at these Amargosa Desert discharge sites ([154724] Paces and Whelan 2001) might be limited to between 17 and 30 m rather than the 80- to 120-m range, as suggested previously.

Although the hydraulic, temperature, and compositional data indicate that the modern SZ hydrology at these sites is complex, interpretations of these data support a regional groundwater source for the deposits without requiring large Pleistocene water table fluctuations either locally or, by inference, up-gradient at Yucca Mountain.

3.5 ENGINEERED BARRIER SYSTEM TESTING

Engineered barrier system testing during the reporting period focused on ventilation testing to support design of the ventilation system, natural convection and thermal conductivity testing to support predictions of the distribution of heat and temperatures in drifts–information that is needed for performance assessment, and crushed column tests to support validation of the geochemical model.

3.5.1 Ventilation Testing

Phase 2 of the quarter-scale test series at the DOE Atlas facility was completed and was comprised of 16 test runs, each lasting between three and ten days. Data processing is underway, but preliminary results indicate that the ventilation system model being used for design is able to accurately predict test results. Data from this test series establishes the credibility of the model and the Project's ability to design and apply ventilation systems to manage thermal loads in the repository.

3.5.2 Thermal Conductivity Field Tests in the Lower Lithophysal Unit

Thermal analyses for the repository horizon that are described in the SSPA Vol. 1 ([155950] BSC 2001) were developed using thermal conductivity estimates based on temperature data collected from several thermal field tests and laboratory measurements of thermal conductivity.

During the reporting period, the first field thermal conductivity test in the Tptpll unit was conducted in the ECRB Cross Drift. The first part of the test was conducted at low heater power, and maximum rock temperatures were maintained below approximately 50°C at saturation conditions consistent with the undisturbed rock mass. During the second part of the test, the heater power was increased to create a dry-out zone in which thermal property measurements could be repeated. This test was terminated prematurely because of equipment failure.

The second thermal conductivity test in the Tptpll unit, also started during the reporting period, is configured like the first, but has three parallel heaters and three parallel temperature sensor holes containing more than 90 sensors total. These field thermal conductivity measurements include the effects of lithophysae too large to be included in laboratory samples. Initial results from the field program (1.74 W/m K) are consistent with the range of thermal conductivities used in the SSPA. The mean SSPA lower lithophysal porosity of 12.5 percent and a saturation of 80 percent result in a model conductivity of 1.75 W/m K, very close to the value measured in the first field test.

3.5.3 Column Testing

THC tests on crushed tuff columns were conducted to provide data for geochemical model validation. These tests evaluated the processes by which minerals and salts in tuff can be dissolved and redeposited in an elevated temperature environment. A test report documenting the findings, *Engineered Barrier Systems Thermal-Hydraulic-Chemical Column Test Report,* is in preparation.

3.6 DISRUPTIVE EVENTS

Disruptive events work during the reporting period supported preparation of SSPA Vol. 1 ([155950] BSC 2001). This work addressed igneous issues related to a range of thermal operating modes for a potential repository and issues raised in meetings with the NRC. An approach involving scaling factors to evaluate the effect of different repository footprints on probabilities of volcanic intersection and number of WPs affected by igneous activity was presented (SSPA Vol. 1, Section 14.3.3.2). For the igneous eruption scenario, new waste particle size distributions were defined for TSPA sensitivity analyses. The minimum waste particle size was reduced by a factor of one-half and the maximum waste particle size was increased by a factor of two (SSPA Vol. 1, Section 14.3.3.4). The mode value for the log-triangular particle size distribution was varied between 0.0002 and 0.02 cm, which was one-tenth to ten times the base case mode value. Also, for the igneous eruption scenario, a new wind speed distribution was developed that provides wind speeds at higher altitudes, consistent with potential ash plume eruption heights (SSPA Vol. 1, Section 14.3.3.5).

Several technical exchanges with the NRC staff occurred during the second half of FY 2001. These meetings focused primarily on igneous issues and resulted in new agreements between DOE and the NRC ([156332] Crump 2001 and [156472] Krier 2001).

INTENTIONALLY LEFT BLANK

SECTION 4 – DESIGN AND CONSTRUCTION

During this reporting period, the Project continued to develop repository design requirements, evolve the surface and subsurface repository design, evolve the WP design, and construct sites for testing activities in the ESF. Advances in these areas are described in the following sections.

4.1 REQUIREMENTS

The Project continued to develop and revise the following documents that establish the repository design requirements and support the Site Recommendation and the LA:

- *Monitored Geologic Repository Project Description Document* ([154136] Curry 2001)
- *Yucca Mountain Site Characterization Project Requirements Document* (YMP-RD) ([154138] YMP 2001).

4.2 WASTE FORM TESTING

Reports and Calculations–The following AMRs were issued during the reporting period:

- *Defense High Level Waste Glass Degradation* ([156805] BSC 2001)
- *Secondary Uranium-Phase Paragenesis and Incorporation of Radionuclides into Secondary Phase* ([154844] BSC 2001)
- *Summary of Dissolved Concentration Limits* ([155455] BSC 2001).

The following calculations were issued during the reporting period:

- *Dissolved Concentration Limits for Certain Radioactive Elements* ([154431] BSC 2001)
- *Effect of Waste Package Materials Surface Area and High-Level Waste Glass Reaction Rate on In-Package Chemistry* ([156806] BSC 2001).

Section 4.2.6 of the S&ER ([153849] DOE 2001), Section 3.3.5 of the PSSE ([155734] DOE 2001), and Section 9 of the SSPA Vol. 1 ([155950] BSC 2001) were written to address waste form issues. Project personnel supported the KTI technical exchanges with the NRC and the NWTRB and Advisory Committee on Nuclear Waste meetings.

Tests involving humid air exposure of two samples of commercial spent fuel rods with perforated cladding showed that the cladding on both samples unzipped at a rate faster than the range used in the S&ER. However, the observed rate of unzipping was consistent with the upper bound value used in the SSPA. This issue is planned to be resolved by updating the unzipping model and incorporating it in the next revision of the current cladding degradation AMR, *Clad Degradation – Summary and Abstraction* ([151662] CRWMS M&O 2001).

4.3 WASTE PACKAGE MATERIAL TESTING

The following AMRs or technical products were updated during this period:

- *Environment on the Surfaces of the Drip Shield and Waste Package Outer Barrier* ([151568] CRWMS M&O 2000)
- *Aging and Phase Stability of Waste Package Outer Barrier* ([151550] CRWMS M&O 2000)
- *Hydrogen Induced Cracking of Drip Shield* ([156934] BSC 2001)
- *Degradation of Stainless Steel Structural Material* ([156356] BSC 2001)
- *Abstraction of Models for Pitting and Crevice Corrosion of Drip Shield and Waste Package Outer Barrier* ([156936] BSC 2001).

These documents were updated primarily to remove the "to be verified" designation of some of the input parameters as the qualification status of the data was upgraded and to correct minor errors. There was no change in the technical content of the documents. In addition to the waste form testing noted above, an engineering calculation, *Plugging of Stress Corrosion Cracks by Precipitates* ([156807] BSC 2001), showed that stress corrosion cracks could become filled with precipitation of minerals (primarily calcite) and corrosion products in less than 1,000 years after the cracking occurs. The implication of this result is significant in that it allows the drip shield to maintain its intended function of diverting dripping water away from the WP. In the case of the WP, crack plugging will significantly reduce the rate of water ingress into the WP, which, in turn, reduces the rate of water egress and the rate of radionuclide release from the WP.

Other Activities–Presentations were made to the NWTRB on the WP performance issues. In addition, WP performance issues were discussed with the NRC staff at various technical exchange meetings.

Also during this reporting period, a Peer Review of the WP materials performance was initiated with a meeting on May 23, 2001. At the meeting, the Project staff made presentations on the status of the WP materials performance issues and path forward work to address these issues. The Peer Review Panel also held an open meeting in Cleveland, Ohio, on July 24, 2001, to hear presentations on WP corrosion by non-Project investigators. In addition, the Peer Review Panel held a number of sub-group meetings to develop a better understanding of the Project technical basis in specific areas of material performance such as localized corrosion, stress corrosion cracking, etc. Based on these meetings and a review of Project documents, the Peer Review Panel prepared an interim report that includes a number of recommendations for additions and changes in the Project's WP development program. The report's preliminary findings were presented at a public meeting held on September 25, 2001. Overall, the preliminary findings support the Project's selection of WP materials and the testing and modeling approach used for the development of the technical bases.

In addition, testing of WP material samples continued. Other tests in progress include electrochemical testing to determine corrosion rates and tests to determine stress corrosion cracking susceptibility. Results of these tests will be documented in future updates of the AMRs or other technical documents.

4.4 WASTE PACKAGE

4.4.1 Reports

The following reports were completed during this reporting period:

Waste Package Project FY-01 Closure Methods Report ([156793] Knapp 2001)–The FY 2001 WP closure weld development task was to identify primary closure welding processes for the SR WP design, evaluate the Alloy 22 (UNS N06022) middle lid joint design, provide a closure weld facility conceptual design and process sequence, and determine minimum detectable flaw size. The identification of primary weld processes and middle lid joint design directly supports the closure weld task. The closure weld facility conceptual design also directly supports the closure weld task by providing a basis for the closure weld (weld cell) portion of the surface facility design. The flaw size detection study supports the nondestructive evaluation task by determining the smallest flaw expected to be detected in a closure weld. Additionally, 240 inches of specimen plates were welded to support the materials testing program.

Waste Package Operations Fabrication Process Report ([156800] Plinski 2001)–This revision updated the document and included information from the FY 2001 closure weld program. The objective of this task was to identify various methods of manufacturing that may be used to fabricate the disposal container, drip shield, and emplacement pallet at whatever manufacturing facilities are awarded the fabrication contracts. This report provides recommended methods and alternative methods for these fabrication operations. The current disposal container configuration is based on the single corrosion resistant barrier with a structural reinforcement cylinder per *Design Analysis for UCF Waste Packages* ([144128] CRWMS M&O 2000), *Design Analysis for the Defense High-Level Waste Disposal Container* ([150823] CRWMS M&O 2000), or *Design Analysis for the Naval SNF Waste Package* ([144132] CRWMS M&O 2000). The designs for the drip shield and emplacement pallet are from the *Design Analysis for the Ex-Container Components* ([146106] CRWMS M&O 2000).

Geochemistry Model Validation Report: External Accumulation Model ([156324] BSC 2001, for KTI Agreements CLST0504, ENFE0503, and RT0403)–The model described in this AMR estimates the quantities of external accumulation of fissionable material for use in external criticality risk assessments.

Geochemistry Model Validation Report: Material Degradation and Release Model ([156790] BSC 2001, for KTI Agreements CLST0504, ENFE0503, and RT0403)–The model described in this AMR estimates the long-term geochemical behavior of WPs and waste forms, specifically the:

- Extent to which criticality control materials remain in the WP
- Extent to which fissile material will be carried out of the WP by infiltrating water
- Chemical composition and amounts of minerals and other solids left in the WP for use in criticality risk assessments.

Radiolytic Specie Generation from Internal Waste Package Criticality ([156787] BSC 2001, for KTI Agreement CLST0505). This calculation determines the amount of radiolytic species (nitric acid) produced by a criticality event.

Waste Package Design Methodology Report ([156789] Brownson 2001). This report describes the analytical methods and processes used by the WP design section to establish the integrity of the various WP designs, the emplacement pallet, and the drip shield. The scope of this report covers the methodology used in criticality, risk-informed, shielding, source term, structural, and thermal analyses. The basic

features and appropriateness of the methods are illustrated, and the processes are defined whereby input values and assumptions flow through the application of those methods to obtain designs that ensure defense-in-depth as well as satisfy requirements on system performance. Such requirements include those imposed by federal regulation, from the DOE, the EPA, and the NRC, and those imposed by the Yucca Mountain Project to meet repository performance goals. The report is to be used to describe the WP design methods and techniques to be used for producing input to the LA Report.

4.4.2 Calculations

The following calculations were completed in this reporting period:

Tip-over of 12-PWR and 24-BWR Waste Packages ([155217] BSC 2001)–This calculation determined the structural response of a 12 PWR SNF and a 24 BWR SNF WP subjected to tip-over onto an unyielding surface (see Section 1.2.2.1.6 of *Uncanistered Spent Nuclear Fuel Disposal Container System Description Document* ([147269] CRWMS M&O 2000). The scope of this calculation was limited to reporting the calculation results in terms of maximum stress intensities in the inner and outer shells of the WPs.

Internal Pressurization Due to Fuel Rod Rupture in Waste Packages ([153755] BSC 2001)–This calculation determined the maximum stresses developed in the WP structural components due to internal pressurization as a result of the fuel rod rupture DBE. The scope of the calculation was limited to reporting the maximum allowable internal pressures for 21-PWR, 44-BWR, 5-DHLW (Defense High-Level Waste) (5-DHLW/DOE SNF-Short), and Naval SNF (Naval SNF-Short and Naval SNF-Long) WP designs.

Horizontal Lifting of 5 DHLW/DOE, 12-PWR Long and 24-BWR Waste Packages ([156794] BSC 2001)–This calculation determined the structural response of a 12-PWR Long, a 24-BWR, and a 5-DHLW/DOE Long SNF WP lifted in a horizontal position. The scope of this calculation was limited to reporting the calculation results in terms of maximum stress intensities in the trunnion collar sleeves. In addition, the maximum stress intensities in the inner and outer shells of the WPs were presented for illustrative purposes.

Waste Package Tip-Over of Naval SNF Long ([156791] BSC 2001)–This calculation determined the structural response of the Naval SNF Long WP subjected to tip-over onto an unyielding surface (see Section 1.2.2.1.6 of the *Naval Spent Nuclear Fuel Disposal Container System Description Document* ([155661] BSC 2001)). The scope of this calculation was limited to reporting the calculation results in terms of maximum stress intensities.

Vertical Drop of 5 DHLW/DOE SNF Long Waste Package ([156798] BSC 2001)–This calculation determined the structural response of the WP dropped vertically from a specified height. A 5-DHLW/DOE WP was used. The scope of this document was limited to reporting the calculation results in terms of stress intensities. The sketches attached to this calculation provide the potential dimensions and material for the 5-DHLW/DOE WP design.

Waste Package Tip-Over of 5-DHLW/DOE SNF Short ([156799] BSC 2001)–This calculation determined the structural response of the 5-DHLW/DOE SNF Short WP subjected to tip-over onto an unyielding surface (see *Defense High Level Waste Disposal Container System Description Document*, Section 1.2.2.1.6 ([147268] CRWMS M&O 2000)). The scope of this calculation was limited to reporting the calculation results in terms of maximum stress intensities.

Lid Lifting Feature Structural Calculation ([156801] BSC 2001)–This calculation determined the structural response of a lid-lifting feature for a lid weighing up to and including 1,500 kg. This lid-lifting feature is used during the lid installation into the WP. Although the sketch (Attachment I of the calculation) refers to a 21-PWR WP concept for LA, the scope of this calculation was limited to lifting WP lids weighting not more than 1,500 kg. The information provided in the sketch and in this calculation is associated with the potential lid-lifting feature design and the results are valid for this design only. Results reported in this calculation are in terms of stress intensities in the lid-lifting feature subjected to static lifting loads.

Tip-Over of the 5 DHLW/DOE SNF - Long Waste Package Containing Fort Saint Vrain HTGR Fuel onto an Unyielding Surface ([155747] BSC 2001)–This calculation determined the structural response of the 5-DHLW/DOE SNF Long WP, containing Fort Saint Vrain high temperature gas reactor Th/U carbide fuel subjected to tip-over onto an unyielding surface (see *Defense High Level Waste Disposal Container System Description Document*, Section 1.2.2.1.6 ([147268] CRWMS M&O 2000)). The scope of this calculation was limited to reporting the calculation results in terms of maximum stress intensities.

Symmetric Rock Fall on Waste Package ([156277] BSC 2001)–This calculation determined the structural response of the Naval SNF WP and the emplacement pallet subjected to the rock fall DBE dynamic loads. The scope of this calculation was limited to reporting the calculation results in terms of maximum stress intensities and residual stresses in the WP, and stress intensities and maximum permanent downward displacements of the emplacement pallet-lifting surface.

Tensile Stresses Developing in an Outer Shell of a Waste Package Mounted on Emplacement Pallet ([156797] BSC 2001)–The reasons for the complete revision of this calculation were changes in both design and fabrication process of the WP, that significantly affect its finite element representation and structural response. The most important change is that instead of the previously used shrink fit the current design features a loose fit between the inner and outer shell of the WP. Hence, in place of the solid connection between the shells, the inner shell is free to move within the outer shell. The finite element representation of the WP is developed in such a way that the loose-fit radial gap between the outer and inner shell is maximized to 4 mm (*Waste Package Operations Fabrication Process Report* p.16 ([152104] BSC 2000)). As a result (keeping in mind the importance of preserving the nominal dimensions of the outer shell intact), the thickness of the inner shell is reduced from 50 mm to 46 mm. Consequently, the inner shell is free to move within the outer shell, as well as the naval canister within the inner shell.

Drop Calculations of HLW Canister and Pu Can-in-Canister ([156784] BSC 2001)–This calculation determined the structural response of the standard HLW canister and the canister containing the cans of immobilized plutonium (Pu "can-in-canister" throughout this document) subjected to drop DBEs during the handling operation. The scope of the HLW canister calculation was limited to reporting the calculation results in terms of stress intensity and effective plastic strain in the canister, directional residual strains at the canister outer surface, and change of canister dimensions. The scope of Pu can-in-canister calculation was limited to reporting the calculation results in terms of stress intensity and effective plastic strain in the canister.

Static Loading of a Waste Package on an Uneven Emplacement Pallet ([156795] BSC 2001)–This calculation determined the structural response of the WP resting on an emplacement pallet under various static conditions. The emplacement pallet was modeled using different heights to account for potential differences. The WP used for that purpose is the 21-PWR. The scope of this document was limited to reporting the calculation results in terms of stress intensities and directional stresses. The sketches attached to this calculation provide the potential dimensions and materials for the 21-PWR WP and emplacement pallet design.

Swing-Down of 21-PWR Waste Package ([156796] BSC 2001)–This calculation determined the structural response of the WP swinging down from a horizontally suspended height. The WP used for that purpose was the 21-PWR WP. The scope of this document was limited to reporting the calculation results in terms of stress intensities.

Repository Multiple Waste Package Thermal Calculation ([156276] BSC 2001)–This calculation evaluated the thermal response of the repository near-field rock temperatures and WP surface temperatures due to the heat production from the WP emplacement. The scope of this calculation was limited to the three-dimensional representation of the multiple WPs emplaced in the repository drift. Variations of the linear heat loading, preclosure ventilation time, and WP heat output were evaluated in this calculation. The calculation results may be used to support the LA design activities.

Natural Convection Calculation of Waste Package Drift Emplacement ([156785] BSC 2001)–This calculation evaluated the buoyancy-induced natural convection effect on the waste placement in the repository drift. The scope of this calculation was limited to verification of the ANSYS-FLOTRAN solution against the Kuehn and Goldstein ([100675] Kuehn and Goldstein 1976) correlation and evaluation of the natural convection effect in the emplacement drift to support engineered barrier system design. The calculation results may be used to support the LA design activities.

Thermal Evaluation of the Fort Saint Vrain Codisposal Waste Package ([155748] BSC 2001)–This calculation evaluated the Fort Saint Vrain co-disposal WP design under nominal MGR conditions. The calculation provided the radial temperature distribution within the Fort Saint Vrain WP.

Dose Rate Calculation for the 21-PWR UCF Waste Package ([153752] BSC 2001)–This calculation determined the maximum dose rate at the external surfaces of a 21-PWR uncanistered fuel WP. The scope was limited to dose rate evaluation at the emplacement of the WP. The results of this calculation were used to assess the shielding performance of the 21-PWR WP concept for LA.

Dose Rate Calculation for the 44-BWR UCF Waste Package ([153753] BSC 2001)–This calculation evaluated the surface dose rates of a 44-BWR uncanistered fuel WP. The scope was limited to the 44-BWR WP concept for LA. The results of this calculation were used to assess the shielding performance of the 44-BWR WP design concept for LA.

Dose Rate Calculation for the Codisposal Waste Package of HLW Glass and the FSVR Fuel ([155749] BSC 2001)–This calculation determined the dose rate at the external surfaces of a WP that contains the Fort Saint Vrain Reactor SNF. The scope of the calculation was restricted to the 5-DHLW/DOE SNF-Long WP. Fort Saint Vrain Reactor SNF was loaded in a long, 18-in. outer diameter DOE standardized SNF canister, and was co-disposed with five 4.5 m-long HLW) glass canisters. Two potential designs for this type of WP are considered in the calculation. The results of this calculation serve to assess the radiation environment of the WP.

Dose Rate Calculation for the Codisposal Waste Package of HLW Glass and the Melt-Dilute Al SNF ([155329] BSC 2001)–This calculation determined the dose rate at the external surfaces of a WP that contains Melt-Dilute Al SNF. The scope of the calculation is restricted to the 5-DHLW/DOE SNF-Short WP. The Melt-Dilute Al SNF was loaded in a short 18-in. outer diameter DOE standardized SNF canister and was co-disposed with five 3-m long HLW glass canisters. Two potential design configurations for this type of WP are considered in the calculation. The results of this calculation serve to assess the radiation environment of the WP.

Radiolytic Production of Nitric Acid on the Radial Surface of the 21-PWR Waste Package ([156786] BSC 2001)–This calculation computed the radiolytic production of nitric acid on the radial surface of the 21-PWR WP. The scope of this calculation was limited to the period of the first 400 years after emplacement. The sketches attached to this calculation provide the potential design information for the 21-PWR WP. The results of this calculation will be used to evaluate radiation-enhanced corrosion of the outer shell of the 21-PWR WP.

Gamma and Neutron Radiolysis in the 21-PWR Waste Package ([156062] BSC 2001)–This calculation computed gamma and neutron dose rates to determine the maximum radiolytic production of nitric acid and other chemical species inside the 21-PWR WP. The scope of this calculation was limited to the period between 5,000 and 100,000 years after emplacement. The results of this calculation were used to evaluate nitric acid corrosion of fuel cladding from radiolysis in the 21-PWR WP.

Waste Form, Heat Output, and Waste Package Spacing for an Idealized Drift Segment ([156792] BSC 2001)–This calculation provided WP design information needed for evaluation of a low-temperature operating mode and for definition of a small WP scenario that can be used for sensitivity studies. This information includes:

- The number of each type of WP (both commercial and non-commercial)
- Decay heat curves as a function of time for each representative (averaged) waste type
- The mass (initial heavy metal) loading for each (averaged) representative waste type
- A representative linear heat load versus time history
- An average decay heat curve for the overall repository
- A variable WP spacing scheme
- An idealized drift segment for use in three-dimensional drift scale model representations
- Quantities and derated initial heat outputs for a small WP scenario.

The scope of this calculation was limited to the period between emplacement and 1,000,000 years after emplacement. The results of this calculation were used to evaluate a low-temperature operating mode for a flexible repository design.

4.5 SURFACE DESIGN

The following document was prepared in this reporting period:

A memorandum, “Design Dose Rate” ([155839] Padula 2001), was prepared during this reporting period. The Project also started the radiation design guide to be used Project-wide for consistent reference to a personnel exposure design dose rate limit of 1,000 mrem/yr based on occupancy factor. In addition, the occupational dose rate limit will be subject to review to ensure that the doses are as low as is reasonably achievable, per 10 CFR 20.1003 [104787].

4.6 REPOSITORY DESIGN

4.6.1 Flexible Repository Design

During this reporting period, the flexible design concept was advanced to include the low-temperature operating mode with the release of three subsurface design documents. Ventilation and subsurface facilities design concepts were combined in the *Lower-Temperature Subsurface Layout and Ventilation Concepts* ([154554] BSC 2001). This analysis presents the repository subsurface layout and ventilation requirements for the lower-temperature design and, together with the *Overall Subsurface Ventilation*

System ([156803] BSC 2001), provides a basis for ventilation layout design to support flexible thermal operating mode concepts. The second document, *Thermal Management Analysis for Lower-Temperature Design* ([154549] BSC 2001), provides the thermal basis for the lower-temperature operating mode design and ventilation. The third, *Shaft Siting and Configuration for Flexible Operating Mode* ([156564] BSC 2001), evaluates the suitability of the shaft locations specified in the lower-temperature subsurface layout. Preparation of baseline drawings has been initiated to reflect the major system concepts developed for the SR.

The basis for these drawings will be the reports, analyses, and calculations used to support the SR. A planning effort has also been initiated to reevaluate subsurface repository concepts in support of the LA design.

4.6.2 Subsurface Design

An Interim Change Notice (ICN) to *Ground Control for Emplacement Drifts for SR* ([155187] BSC 2001) was completed. The primary purpose of the ICN is to document the ground support system response to a low-temperature repository condition. The revised analysis now evaluates the ground control approach in emplacement drifts for both low- and high-temperature repository operating modes. To account for effects of both low temperature and longer ventilation periods on ground support materials, an ICN to *Longevity of Emplacement Drift Ground Support Materials* ([155667] BSC 2001) was also processed. Additional work included validation of the ground control analysis software code, UDEC (Universal Distinct Element Code), Version 3.0; identification and planning of ground control products to support the LA; and definition of resolution approaches and products for Repository Design Thermal-Mechanical Effects Key Technical Issues. In progress is a re-evaluation effort to define the work scopes for ground control system quality classifications, concrete and/or shotcrete lining for emplacement drifts, ground support installation sequencing, and maintenance strategies.

Gantry Structural/Control System Analysis ([154553] BSC 2001) was completed on schedule. This analysis describes gantry operations in handling WPs and emplacement pallets in and near the emplacement drifts. Work was completed on *Lower Temperature Invert Design for Diffusion Barrier* ([155718] BSC 2001). This analysis investigates various alternatives to emplacement drift invert structural design, as well as outlines the options for including diffusive barrier material in these designs. Also completed was the *Subsurface Shielding Source Term Specification Calculation* ([156424] BSC 2001). The purpose of this calculation is to establish appropriate and defensible WP radiation source terms for use in repository subsurface shielding design.

4.7 EXPLORATORY STUDIES FACILITY AND CONSTRUCTION

4.7.1 Site Testing and Investigation

Operations and maintenance of the ESF and Busted Butte Facility were provided in support of continuing testing activities. Construction of the Niche 5 Collection Wings was completed. The upgrade of the underground lighting system is underway and projected to be complete during FY 2002. Construction of the ESF Switch Gear Building continued through this reporting period and will be complete in FY 2002. The ESF Visual Warning System drawings were issued during this period.

Operation and maintenance of the ESF will continue in support of testing activities in FY 2002. The Busted Butte Facility will be placed in temporary shutdown in early FY 2002. System upgrades at the facility will continue through the remainder of the fiscal year.

4.7.2 Geochemical Analysis

4.7.2.1 Geochemical Analysis of ECRB Cross Drift Rock Cores

The interaction between the Engineered Barrier System (WP, drip shields, etc.) and the host rock (minerals, contained water, and gases), under temperatures well above natural ambient temperatures, is being investigated to assess the performance of the potential repository for long-term containment of nuclear waste ([155696] Peterman and Cloke 2001). The geochemistry and mineralogy of the rock mass hosting the emplacement drifts is being investigated to assess the role of the natural system in the near-field environment. The chemical composition of the phenocryst-poor member of the Topopah Spring Tuff has been characterized by numerous chemical analyses of outcrop samples and of core samples obtained by surface-based drilling. Those analyses have shown that the phenocryst-poor member is remarkably uniform in composition both vertically and laterally. To verify this geochemical uniformity and to provide rock analyses of samples obtained directly from the potential repository block, major and trace elements were analyzed in core samples obtained from drill holes in the ECRB Cross Drift. Duplicate major and trace-element chemical analyses of 20 samples from the ECRB Cross Drift representing several lithostratigraphic zones, confirmed the remarkable compositional uniformity of the phenocryst-poor member of the Topopah Spring Tuff. Localized deposits of minerals in lithophysal cavities and low-temperature calcite and opal coatings in fractures and cavities that were exposed to a vapor-phase, were avoided in sampling. However, because minerals exposed to the vapor-phase are mostly silica polymorphs and alkali feldspar in approximately the same relative abundance as in the rocks, inclusion of such deposits in larger scale sampling, likely would not change the bulk composition of the phenocryst-poor member. Inclusion of low-temperature calcite and opal coatings in large bulk samples could increase the CaO and CO_2 contents slightly, but the SiO_2 contents would not be appreciably affected.

4.7.2.2 Geochemical Analysis of ESF Dust Samples

Work continued on investigation of water-rock interaction on EBS materials. Phase I geochemical analyses of major and trace elements (including Pb) in 27 samples of dust collected throughout the ESF have been completed and are currently being synthesized for inclusion in a data package. The elements As and Hg were analyzed separately because of specific interest in those elements with regard to canister corrosion. Geochemical analyses are now being evaluated to determine the specific components of dust samples from sources introduced into the ESF during construction and subsequent operation. Rare-earth element analyses of ECRB Cross Drift tuff samples were acquired to serve as a basis of comparison with dust samples. Rare earth element patterns differ significantly between the crystal-poor rhyolites and the crystal-rich trachytes. Thus, the rare earth element patterns for the dust can be used to estimate the relative abundance of those source rocks in the ESF dust load. Sources of the dust, with particular reference to elements that are enriched significantly over rock values, are being evaluated through the construction of spider diagrams in which the dust values are ratioed to the average values for the crystal-poor rhyolite.

Phase II collection of dust is being designed. A heavy-duty battery-powered vacuum cleaner has been procured, and a miniature dust-collecting cyclone is being constructed and will be interfaced with the vacuum cleaner. This system will facilitate the Phase II sample collection and will provide better estimates of the mass of dust accumulated per unit surface area of accumulation. Phase II will also include deployment of passive dust collectors throughout the ESF.

INTENTIONALLY LEFT BLANK

SECTION 5 – REPOSITORY PERFORMANCE

During this reporting period, the Project accomplished several advances in developing the topics of preclosure radiological safety assessment, postclosure performance assessment, and performance confirmation. These advances are described in the following sections.

5.1 PRECLOSURE SAFETY ASSESSMENT

An update was made to the *Preliminary Preclosure Safety Assessment for Monitored Geologic Repository Site Recommendation* ([154857] BSC 2001) to include an analysis of lower repository temperature operational modes (and corresponding longer preclosure operating periods). The purpose of this preliminary preclosure safety assessment is to document potential operations during the preclosure period, identify potential facility hazards and their initiating events, identify MGR DBEs, evaluate DBE occurrence frequencies and consequences, and identify those SSCs important to safety. This report also provides the MGR strategies for criticality safety, radiation protection, and fire protection, along with a description of the provisions for the control and management of low-level radioactive waste. Descriptions of the MGR site characteristics and facility design are provided to support the identification of hazards and the evaluation of DBEs. This report supports Site Recommendation activities, and was used to support conclusions concerning the preclosure safety assessment included in Chapter 2 of the PSSE ([155734] DOE 2001).

Several calculations were completed in the reporting period, including a calculation titled *Disposable Canister Waste Acceptance Criteria* ([153564] BSC 2001), which supports development of an update to the *Waste Acceptance System Requirements Document* ([110306] DOE 1999). The calculation titled *Significant Radionuclides Determination* ([156955] BSC 2001) identifies radionuclides that are significant to off-site doses from potential preclosure events for SNF and HLW expected to be received at the potential MGR. In the *Canister Transfer System Event Sequence Calculation* ([156956] BSC 2001) an assumed range of canister and Canister Transfer System performance allocation failure probabilities was evaluated to determine the effect of these failure probabilities on the frequency of a radionuclide release. A DBE-related analysis titled *DOE SNF BDBE Dose Calculations* ([156957] BSC 2001) was also issued during the performance period. This analysis was performed to provide a beyond DBE dose consequence analysis of DOE SNF. The beyond DBE calculation included a non-mechanistic initiating event and the sequence of events that follow to cause a radiological release. The beyond DBE calculation resulted in an unmitigated dose (i.e., no radionuclides removed by high-efficiency particulate air filtration) that was below regulatory limits. These and other similar DBE analyses and calculations form the basis for the MGR preclosure safety case. Results of these analyses may also be used to determine or modify the QA classification level of repository SSCs.

Work in progress includes the preparation of Revision 1 of the calculation titled *Commercial SNF Accident Release Fractions* (in progress, see Appendix B). This and other calculations and evaluations will be used to support future preclosure safety assessments, including those performed to support proposed License Application activities. Results of these analyses may also be used to determine or modify the QA classification level of repository SSCs. Work is underway on an update to the procedure for the classification of structures, systems and components important to safety. In addition, a desktop guide is under development to describe the overall MGR approach for the preparation of the PSA. The PSA addresses the safety of the MGR operations area during the preclosure period (i.e., the period before permanent closure) to demonstrate compliance with the performance objectives of 10 CFR 63 final rule ([156671] 66 FR 55732). Work is also underway to support an update to Section 5 of the S&ER ([153849] DOE 2001). Other work in progress involves identification of aircraft hazards and vicinity map, as well as work to support the selection of design concepts to be used in the proposed MGR design for License Application.

Technical exchange meetings were held with the NRC to discuss the development of PSA and PSA products. Topics discussed included the identification of hazards and initiating events, the identification of event sequences, consequence analysis, level of design details, pre-closure criticality issues, and engineered barrier system design and fabrication. Four items were identified as commitments as part of the NRC/DOE agreements resulting from the technical exchange meeting, including identification of aircraft hazards and vicinity map; the PSA guide; an update to the procedure for the classification of SSCs important to safety; and an update to the analysis of tornado winds and tornado-driven missiles.

5.2 POSTCLOSURE PERFORMANCE ASSESSMENT

5.2.1 Performance Assessment

During this reporting period, the SSPA Vol. 2 ([154659] BSC 2001) was developed and issued. SSPA Vol. 1 ([155950] BSC 2001) presents the new information developed since completion of the initial AMRs, PMRs, the TSPA-SR ([153246] CRWMS M&O 2000), and the S&ER ([153849] DOE 2001). SSPA Vol. 2 describes the supplemental TSPA analyses conducted using the updated information documented in SSPA Vol. 1 and addresses the performance of a potential repository at Yucca Mountain considering the most recent scientific data, updated models, quantification of uncertainty, and a lower-temperature operating mode.

Total System Performance Assessment–Analyses for Disposal of Commercial and DOE Waste Inventories at Yucca Mountain–Input to Final Environmental Impact Statement and Site Suitability Evaluation ([156460] BSC 2001) was also issued. This report documented the calculations of the estimated effects on long-term dose due to the potential disposal of commercial SNF, DOE SNF, HLW, and DOE Greater than Class C, and Special Performance Assessment Required nuclear waste at the potential repository.

Other performance assessment activities included:

- Participation in technical exchanges with the NRC regarding FEPs, TSPA methodology, and igneous activity consequence modeling
- Support for an international peer review of the TSPA-SR ([153246] CRWMS M&O 2000) by the International Atomic Energy Agency and National Energy Agency
- Support for interactions with the NWTRB
- Support for various reviews of the TSPA-SR, including the addressing of NRC comments.

5.2.2 Near Field Environment

Near-field environment work focused on preparation of Sections 4.3.5 through 4.3.7 of the SSPA Vol. 1 ([155950] BSC 2001). These sections address the coupled effects of TH, THC, and THM processes on seepage into emplacement drifts. See Section 3.2.2 of this document for further details of near field environment analysis and results presented in the SSPA Vol. 1 and Vol. 2 ([155950, 154659] BSC 2001).

Large-scale, field thermal tests are also continuing to support the characterization of Yucca Mountain as described in Section 3.2.2 of this document.

5.2.3 Engineered Barrier System

Presentations were made to the NWTRB in May 2001, June 2001, and September 2001 that addressed quantified and unquantified uncertainties, thermal operating modes, and thermal-hydrologic and thermal-mechanical effects. Presentations were also made to the NRC in August 2001 which addressed the SSPA Vol. 1 and Vol. 2 ([155950, 154659] BSC 2001).

The following AMRs were updated during this period:

- *Drift Degradation Analysis* ([156304] BSC 2001)
- *Flow of Water and Pooling in a Waste Package* ([152248] BSC 2001)
- *Invert Diffusion Properties Model* ([156700] BSC 2001)
- *EBS Radionuclide Transport Abstraction* ([155638] BSC 2001).

The following calculations were completed during this reporting period:

- *In-Drift Microbial Communities Model Validation Calculations* ([155810] BSC 2001)
- *Microbial Transport Sensitivity Calculations* ([155809] BSC 2001).

5.2.4 Unsaturated Zone Flow and Transport

The focus of the UZ flow and transport modeling investigations has been redirected to the preparation of relevant sections of the SSPA Vol. 1 ([155950] BSC 2001). A number of new models have been set up and numerous simulations performed to support sensitivity analyses of unquantified uncertainties and the flexible operating mode. The major UZ developments presented in the SSPA are listed below.

- Incorporated climate predictions for longer-term scenarios (to 1,000,000 years) into the infiltration and UZ flow modeling. Three additional full-glacial climate states are specified within the 1,000,000-year period, with different climate stages timed with the earth orbital clock. Full-glacial stages encompass about 21 percent over the next 1,000,000 years.

- Developed a more refined flow model for the PTn hydrogeologic unit. With its characteristics of high matrix porosity and low fracture frequency, and with the existence of tilted layers of nonwelded vitric and bedded tuff units, PTn can effectively damp out episodic infiltration pulses and divert percolating water to the intercepting faults and fault zones. The difference between infiltration distribution above the PTn and percolation distribution below the PTn is substantiated by geochemical data collected in the field.

- Considered the effects of a lower thermal operating mode on mountain-scale thermohydrologic processes. Thermal conductivity and heat capacity of the rock mass are modified to account for the lithophysal porosity in the tuff matrix. This lower-temperature operating mode results in a maximum temperature of 85°C at the drift wall, and therefore no boiling within the rock.

- Evaluated the effects of THC processes at the mountain-scale using a new model of thermal loading effects on water flow and geochemistry in the UZ.

- Evaluated the THM effects at the mountain-scale using a new coupled THM model.

- Data from long-term liquid-release experiments were analyzed to reduce the estimation uncertainty of seepage–relevant parameters and obtain estimates for the previously untested lower lithophysal zone of the Topopah Spring Tuff unit.

- Distributions of flow focusing factors were developed as part of the seepage abstraction process to account for potentially increased local flow rates as a result of intermediate-scale flow channeling.

- A detailed modeling study was performed to address the potential for seepage enhancement due to ground support measures.

- A new seepage prediction model based on three-dimensional degradation profiles was developed to further study the impact of heterogeneity and degradation effects on seepage.

- A refined modeling study was performed to reduce conceptual uncertainties regarding grid resolution and heterogeneity. The study also examined the impact of lithophysal cavities on thermal properties; the potential for liquid water to penetrate a superheated region, causing episodic seepage events; and the development of a vaporization barrier. Moreover, percolation flux was calculated for a range of thermal operating modes.

- Additional validation studies were performed, enhancing the confidence in the THC modeling approach. Sensitivity analyses were performed to examine different in-drift designs, different heterogeneous host rock units, different systems of components and minerals, different kinetic models for mineral-water interactions, different permeability-porosity relations during precipitation and dissolution, and changed thermodynamic data and initial conditions. Additional studies of coupled processes were performed for an extended range of temperatures covering various thermal operating modes.

- A distinct-element analysis was revised and extended to provide a more robust estimate of TM effects in fracture permeability. In addition, a fully coupled THM continuum model was developed and calibrated against air-permeability data from three niches and the Drift Scale Test area.

- The effects of flow diversion around waste emplacement drifts (drift shadow zone) on radionuclide transport from waste emplacement drifts are considered directly in process model calculations. Radionuclide releases are modeled from the emplacement drift to the rock matrix and fractures according to the physical processes that govern radionuclide movement. The effects of reduced water saturations and flow rates beneath the emplacement drift are considered in process model calculations for radionuclide transport away from the drifts.

- Matrix-grid discretization effects in a dual-permeability model are investigated with respect to model results for radionuclide transport. A comparison of transport calculations using a single-matrix grid model and a multiple-matrix grid model shows that the leading edge of a radionuclide breakthrough curve will arrive significantly earlier using the single-matrix grid model.

- Calculation schemes for radionuclide transport include particle tracking methods and direct numerical solutions of the conservation equations. The different schemes can result in different model predictions, particularly because of differences in the approaches used for matrix diffusion. A comparison is made for the results from three different simulation methods for UZ transport: FEHM V2.10 ([132447] LANL 2000), DCPT V1.0 ([132448] LBNL 1999), and T2R3D V1.4 ([113942] LBNL 1999).

- Sensitivity calculations were performed (see Section 11.3.4 of SSPA Vol. 1([155950] BSC 2001)) to investigate the changes in radionuclide transport behavior that would result if the baseline repository footprint were extended to the south.

The results of the numerical simulations have been summarized in SSPA Vol. 1 ([155950] BSC 2001) Section 3 (UZ Flow), Section 4 (Seepage), and Section 11 (UZ Transport).

5.2.4.1 Revision of Unsaturated Zone Analysis/Model Reports

The following AMRs were updated during this reporting period:

- *Features, Events, and Processes in UZ Flow and Transport* ([154826] BSC 2001)
- *Drift-Scale Coupled Processes (DST and THC Seepage) Models* ([154677] BSC 2001).

In addition, a change to AMR *Future Climate Analysis* is currently in preparation.

5.2.4.2 Scientific and Technical Work Activities

Laboratory and field testing are continuing, as described in Section 3.3 of this document, to support the development or refinement of UZ models.

5.2.4.3 Workshops and Presentations

Presentations were made to the NRC at the technical exchange meetings in August and September 2001, which addressed, respectively:

- TSPA and Integration
- Range of Thermal Operating Conditions.

Also, presentations were made to the NWTRB in June 2001, which addressed UZ flow, transport, and coupled processes that are addressed in the SSPA Vol. 1 ([155950] BSC 2001).

5.2.5 Saturated Zone Flow and Transport

New SZ flow and transport information is given in the SSPA Vol. 1 ([155950] BSC 2001). This new information was developed since completion of the initial AMRs, the PMRs, the TSPA-SR ([153246] CRWMS M&O 2000), and the S&ER ([153849] DOE 2001). Much of the new information reported in the SSPA came from sensitivity analyses and includes the following:

- New data and analyses to quantify previously unquantified uncertainties and to establish new uncertainty ranges.

- New data and new technical work at the process-model level.

- Multiple lines of evidence, including natural analogues, hydrochemical and isotopic analyses, single-well tracer testing at the Alluvial Testing Complex, and transport studies on blocks of intact tuff mined from the Busted Butte Unsaturated Zone Facility. These multiple lines of evidence are used to support the identification of processes affecting flow and transport, the numerical modeling of the processes, and the modeling predictions.

The following list contains results from the additional analyses performed in the SSPA Vol. 1 and Vol. 2 ([155950, 154659] BSC 2001):

- Calculations examining the influence of alternate conceptual models for the large hydraulic gradient showed relatively small changes in the transport flow paths from the repository to the compliance boundary.

- Recently collected water-level data and their interpretation suggest that the large hydraulic gradient north of Yucca Mountain may not be as large as previously thought due to reinterpretation of the data, but that hydraulic gradients along the potential flow path from the site remain unchanged with the new data.

- Reinterpretation of the information relevant to the estimation of the specific discharge parameter has led to a narrower uncertainty distribution for this important parameter.

- The report presents preliminary results of single well tracer tests in the Alluvial Testing Complex that are consistent with the effective continuum model assumed for transport in the alluvium.

- Simulations using the new compliance boundary mandated by 40 CFR 197.12 [155238] suggest somewhat shorter travel times from the repository to the boundary due to the shorter flow path (reduced from 20 km to roughly 18 km).

The Project continued generating complete analysis and breakthrough curves at the final EPA compliance point of approximately 18 kilometers south of the potential repository. This information, along with the information from the SSPA Vol. 1 ([155950] BSC 2001), was incorporated into the PSSE ([155734] DOE 2001).

5.2.5.1 Revision of Saturated Zone Analysis/Model Reports and Updating of Saturated Zone Flow and Transport Process Model Report

The following documents were updated and issued during this reporting period.

- *Calibration of the Site-Scale Saturated Zone Flow Model* ([155974] BSC 2001)
- *Probability Distribution for Flowing Interval Spacing* ([156965] BSC 2001).

Work on the following new AMRs was initiated during this period.

- *Saturated Zone Flow Patterns and Analyses*
- *Saturated Zone In-Situ Testing*.

5.2.5.2 Scientific and Technical Work Activities

The following is a list of some of the scientific and technical work activities that took place during this reporting period. Section 3.4 of this document contains additional details of SZ work activities.

- Lithologic descriptions and stratigraphic correlation were completed for the Phase I and Phase II boreholes drilled under the NC-EWDP. Geologic cross sections Nye-1, Nye-2, and Nye-3 were completed. The cross sections and associated geologic interpretations will be used as refinements to the hydrogeologic framework for the site-scale SZ flow and transport model as they are developed.

- The SZ testing program at the Alluvial Testing Complex has generated a considerable amount of additional data since publication of the SSPA Vol. 1 and Vol. 2 ([155950, 154659] BSC 2001). Single well injection-withdrawal tracer testing in the alluvium at the NC-EWDP-19D1 location supports the conclusion reported in the SSPA that a single-porosity conceptual transport model applies to the alluvium at the NC-EWDP-19D1 location, at least in the uppermost screened interval in the well.

- Numerous radionuclide sorption and transport tests not available for inclusion in the SSPA have been conducted as part of the SZ testing program in the past year. Both laboratory batch sorption and column transport tests have been conducted using water and alluvium material from wells NC-EWDP-19D1 and NC-EWDP-19P. K_d values for Li as a function of smectite and clinoptilolite weight percentage in the alluvium were reported. Also, K_d values of various radionuclides of interest were measured.

- Activities to support site recommendation continue. Various technical issues were addressed or are in the process of being addressed with field and laboratory investigations. These investigations and the resulting data are analyzed and reported in Project documents that support the SR.

5.2.5.3 Workshops and Presentations

Presentations were made to the NRC and the NWTRB at the various technical-exchange meetings held during this reporting period. Issues, such as the following, were addressed at these meetings:

- Repository design
- Unsaturated and saturated flow under isothermal conditions
- Features, events, and processes
- SZ flow and transport model
- SZ work discussed in the SSPA documents
- Radionuclide transport.

Project representatives attended various workshops during the reporting period. These included:

- Workshop on the flow path
- Workshop on Nye County stratigraphy and lithology
- Devils Hole Workshop
- Death Valley Regional Flow System Steady-State Model meeting and workshop
- Workshop on matrix diffusion
- SZ/UZ integration workshop with the USGS regional model team.

The Final EIS (in progress, see Appendix B) was supported with simulations using the site-scale flow and transport model.

5.2.6 Biosphere

5.2.6.1 Technical Effort

The Biosphere technical effort in this period focused on analyses and documentation to support the SSPA Vol. 1 ([155950] BSC 2001, Section 13). This section documented work performed since the generation of the biosphere results used in TSPA-SR ([153246] CRWMS M&O 2000) and as such contains work performed in both this and the previous reporting period.

The following biosphere topics were analyzed and reported in the SSPA Vol. 1:

- The sensitivity of BDCFs to the definition of the receptor of interest
- A preliminary comparison of the implications on BDCFs of applying International Commission on Radiological Protection (ICRP) Publication 72 ([152446] ICRP 1996) dose assessment methods as opposed to the methods based on ICRP Publication 30 ([110386] ICRP 1979)
- An evaluation of the uncertainties associated with radionuclide removal from soil by leaching
- The uncertainty in groundwater usage by the hypothetical community
- The inhalation pathway model update
- The impacts of climate change on BDCFs
- Derivation of the scenario-specific BDCFs for ^{79}Se and ^{237}Np.

Since the SSPA, additional evaluations have been conducted to develop the BDCFs for the reasonably maximally exposed individual for the groundwater release and the volcanic release exposure scenarios. This work was performed in support of the *Draft Environmental Impact Statement for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada*, ([105155] DOE 1999) and the PSSE ([155734] DOE 2001). The updated consumption rates of the locally produced food and water were used to develop all BDCF sets. The continuation of this work involved the development of the BDCFs sets for the reasonably maximally exposed individual using ICRP Publication 72 dose coefficients. The implications of applying ICRP Publication 72 dose coefficients on the TSPA results were then evaluated.

Biosphere model validation has been an ongoing activity throughout this period.

5.2.6.2 Interactions with NRC

Technical exchange meetings with the NRC on the KTIs involving the biosphere were supported. The KTIs were the Total Performance Assessment and Integration KTI and the Igneous Activity KTI. Agreements were reached with the NRC on all biosphere issues, six with respect to Igneous Activity and eight with respect to Total Performance Assessment and Integration.

5.2.7 Disruptive Events

Disruptive events work performed during the reporting period supported preparation of the SSPA ([155950] BSC 2001). This work addressed igneous issues related to a range of thermal operating modes for a potential repository and issues raised in meetings with the NRC including the following:

- An approach for using scaling factors to evaluate the effect of different repository footprints on the probabilities of volcanic intersection and on the number of WPs affected by igneous activity ([155950] BSC 2001, Section 14.3.3.2).

- New waste particle size distributions were defined for the igneous eruption scenario used for TSPA sensitivity analyses. The minimum waste particle size was reduced by a factor of one-half and the maximum was increased by a factor of two ([155950] BSC 2001, Section 14.3.3.4). The mode value for the log-triangular particle size distribution was varied between 0.0002 and 0.02 cm, or a range of one-tenth to ten times the base case mode value.

- Also for the igneous eruption scenario, a new wind speed distribution was developed that provides wind speeds at higher altitudes, consistent with potential ash plume eruption heights ([155950] BSC 2001, Section 14.3.3.5).

- A sensitivity analysis, shown in Section 3.3.1.2.3 of the SSPA Vol. 2 ([154659] BSC 2001), compared the relative contribution to dose of WPs in two different damage zones: a few packages completely compromised nearest a dike intrusion into a drift; and a greater number of packages partly damaged further down the drift from a dike. The results of the analysis ([154659] BSC 2001, Section 3.3.1.2.3) show that the greater contribution to dose would come from the completely compromised packages nearest the dike intrusion.

5.2.8 Waste Form

During this reporting period, the development of several key documents was supported. Section 4.2.6 of the S&ER ([153849] DOE 2001), Section 3.3.5 of the PSSE ([155734] DOE 2001), and Chapter 9 of the SSPA Vol. 1 ([155950] BSC 2001) address waste form issues.

The Project also supported the KTI technical exchange meetings with the NRC, the NWTRB, and the Advisory Committee on Nuclear Waste.

The following Calculation Reports and AMRs were issued during the reporting period:

- *Defense High Level Waste Glass Degradation* ([156805] BSC 2001)

- *Dissolved Concentration Limits for Certain Radioactive Elements* ([154431] BSC 2001)

- *Effect of Waste Package Materials Surface Area and High-Level Waste Glass Reaction Rate on In-Package Chemistry* ([156806] BSC 2001)

- *Secondary Uranium-Phase Paragenesis and Incorporation of Radionuclides into Secondary Phases* ([154844] BSC 2001)

- *Summary of Dissolved Concentration Limits* ([155455] BSC 2001).

Flow-through tests were a source of data for the generation of the commercial SNF radionuclide release model. A re-analysis of some archived leachate samples from the commercial SNF flow-through tests showed uranium concentrations that averaged 20 percent higher than in the original measurements. It is currently hypothesized that fine particulate and/or colloidal release may be responsible for the higher uranium concentration values. The issue will be further analyzed and, if appropriate, the commercial SNF release model revisited in a revision to the current commercial SNF release AMR, *CSNF Waste Form Degradation: Summary Abstraction* ([136060] CRWMS M&O 2000).

5.2.9 Waste Package

Presentations were made to the NWTRB on the WP performance issues. In addition, WP performance issues were discussed with NRC staff at various technical exchange meetings.

Also, during this reporting period, a Peer Review Panel of the Waste Package Materials Performance was formed and an initial meeting (open to the public) was held on May 23, 2001. At the meeting, the Project made presentations on the status of the WP materials performance issues and on the path forward work to address these issues. On July 24, 2001, the Peer Review Panel held an open meeting in Cleveland, Ohio, to hear presentations on WP corrosion topics presented by non-Project investigators. The Peer Review Panel also held a number of sub-group meetings to develop a better understanding of the Project technical basis in specific areas of material performance such as localized corrosion, stress corrosion cracking, etc. Based on these meetings and a review of Project documents, the Peer Review Panel prepared an Interim Report that includes a number of recommendations for additions and changes in the Project's WP development program. The report's preliminary findings were presented at a public meeting held on September 25, 2001. The preliminary findings support the Project's selection of WP materials and the testing and modeling approach used for the development of the technical bases.

The following AMRs or technical products were updated during this period:

- *Environment on the Surface of the Drip Shield and Waste Package Outer Barrier* ([155640] BSC 2001)
- *Aging and Phase Stability of Waste Package Outer Barrier* ([151550] CRWMS M&O 2000)
- *Hydrogen Induced Cracking of Drip Shield* ([156934] BSC 2001)
- *Degradation of Stainless Steel Structural Material* ([156356] BSC 2001)
- *Abstraction of Models for Pitting and Crevice Corrosion of Drip Shield and Waste Package Outer Barrier* ([156936] BSC 2001).

In addition, an engineering calculation ([156807] BSC 2001) on the plugging of stress corrosion cracks by precipitation of minerals and corrosion products was completed. The results of the calculations showed that stress corrosion cracks could become filled with precipitation of minerals (primarily calcite) and corrosion products in less than 1000 years after the cracking occurs. The implication of this result is significant from the standpoint of the capability of the drip shield to perform its intended function of diverting dripping water away from the WP. In the case of the WP, crack plugging will significantly affect the rate of water ingress into the WP, which in turn affects the rate of water egress and the rate of radionuclide release from the WP.

5.3 PERFORMANCE CONFIRMATION

The performance confirmation program, which began during site characterization and continues until permanent closure, includes activities to collect and analyze repository performance data to ensure that conditions encountered, and changes in those conditions, are within the limits to be stated in the LA. The performance confirmation program will determine whether the natural systems, engineered systems, and system components function as intended and anticipated.

The *Performance Confirmation Plan* ([150657] CRWMS M&O 2000) and the *Monitored Geologic Repository Test & Evaluation Plan* ([151965] CRWMS M&O 2000) are being updated. This work will evaluate possible changes in the testing program due to revision of YMP requirements, the evolution of the design concept, and the finalization of 10 CFR 63 and 40 CFR 197.

INTENTIONALLY LEFT BLANK

SECTION 6 – EPILOGUE

Several important developments, shown here chronologically, have occurred on the Project since the close of the reporting period on September 30, 2001. As of February 15, 2002, these developments include the following:

- The DOE discussed with the NRC technical staff, at an Appendix 7 meeting in October 2001, the plans to discontinue monitoring in UZ surface-based boreholes UE-25 UZ#5, UE-25 UZ#4, and USW NRG-7a. The monitoring was discontinued in mid-December 2001.

- Public hearings and public comment periods on the Secretary of Energy's consideration of the Yucca Mountain site for possible recommendation to the President as a nuclear waste repository were announced in Federal Register notices dated October 5, 2001 ([156973] 66 FR 51027); November 14, 2001 ([156976] 66 FR 57049); and November 21, 2001 ([157062] 66 FR 58460). The public hearings in Las Vegas, Amargosa Valley, and Pahrump, Nevada, were held on September 5, October 10, and October 12, 2001, respectively. Additional public hearings were held in all 17 counties in Nevada and in Inyo County, California. The public comment periods were extended through December 14, 2001.

- On November 2, 2001, the NRC promulgated the final rule on the Disposal of High-Level Radioactive Wastes in a Proposed Geologic Repository at Yucca Mountain, Nevada, 10 CFR Part 63 ([156671] 66 FR 55732). The final rule became effective on December 3, 2001, and was codified as 10 CFR 63, "Disposal of High-Level Radioactive Waste in a Geologic Repository at Yucca Mountain, Nevada" [156605].

- On November 14, 2001, DOE promulgated the final rule on the Yucca Mountain Site Suitability Guidelines, 10 CFR 963 ([156908] 66 FR 57298). The rule became effective on December 14, 2001.

- On January 10, 2002, the Secretary of Energy, Spencer Abraham, notified Nevada Governor Kenny Guinn and the Nevada Legislature, that he intends to recommend to President Bush that the Yucca Mountain site is scientifically sound and suitable for development as the nation's long-term geological repository for nuclear waste.

- On February 14, 2002, the Secretary of Energy, Spencer Abraham, recommended to President George W. Bush that he approve the Yucca Mountain site for development of a nuclear waste repository.

- On February 15, 2002, President George W. Bush notified Congress that he considers Yucca Mountain qualified for application for a repository, and recommended it for that purpose.

INTENTIONALLY LEFT BLANK

SECTION 7 – REFERENCES

NOTE: References are cited in text by DIRS number and numerically sorted by DIRS number in this list. The unique DIRS number is placed in the text before the author-date callout (e.g., ([155950] CRWMS M&O 2000), and is shown in the first column of this list. The list is divided into three sections: Documents Cited; Codes, Standards, and Regulations; and Source Data, Listed by Data Tracking Number.

7.1 DOCUMENTS CITED

100171 Paces, J.B.; Neymark, L.A.; Marshall, B.D.; Whelan, J.F.; and Peterman, Z.E. 1996. *Letter Report: Ages and Origins of Subsurface Secondary Minerals in the Exploratory Studies Facility (ESF)*. Milestone 3GQH450M, Results of Sampling and Age Determination. Las Vegas, Nevada: U.S. Geological Survey. ACC: MOL.19970324.0052.

100675 Kuehn, T.H. and Goldstein, R.J. 1976. "Correlating Equations for Natural Convection Heat Transfer Between Horizontal Circular Cylinders." *International Journal of Heat and Mass Transfer, 19,* (10), 1127-1134. New York, New York: Pergamon Press. TIC: 238411.

101023 Triay, I.R.; Cotter, C.R.; Huddleston, M.H.; Leonard, D.E.; Weaver, S.C.; Chipera, S.J.; Bish, D.L.; Meijer, A.; and Canepa, J.A. 1996. *Batch Sorption Results for Neptunium Transport Through Yucca Mountain Tuffs*. LA-12961-MS. Los Alamos, New Mexico: Los Alamos National Laboratory. ACC: MOL.19980924.0050.

105155 DOE (U.S. Department of Energy) 1999. *Draft Environmental Impact Statement for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada*. DOE/EIS-0250D. Summary, Volumes I and II. Washington, D.C.: U.S. Department of Energy, Office of Civilian Radioactive Waste Management. ACC: MOL.19990816.0240.

110306 DOE 1999. *Waste Acceptance System Requirements Document.* DOE/RW-0351, Rev. 03. Washington, D.C. U.S. Department of Energy, Office of Civilian Radioactive Waste Management. ACC: HQO.19990226.0001.

110386 ICRP (International Commission on Radiological Protection) 1979. *Limits for Intakes of Radionuclides by Workers.* Volume 2, No. 3/4 of *Annals of the ICRP*. Sowby, F.D., ed. ICRP Publication 30 Part 1. New York, New York: Pergamon Press. TIC: 4939.

113942 LBNL (Lawrence Berkeley National Laboratory) 1999. *Software Code: T2R3D V1.4.* V1.4. SUN, DEC / ALPHA. 10006-1.4-00.

132447 LANL (Los Alamos National Laboratory) 2000. *Software Code: FEHM.* V2.10. SUN Ultra Sparc, PC. 10086-2.10-00.

132448 LBNL 1999. *Software Code: DCPT.* V1.0. PC. 10078-1.0-00.

135621 NRC (U.S. Nuclear Regulatory Commission) 1999. *Issue Resolution Status Report Key Technical Issue: Structural Deformation and Seismicity.* Rev. 2. Washington, D.C.: U.S. Nuclear Regulatory Commission. ACC: MOL.19991214.0623.

136060 CRWMS M&O (Civilian Radioactive Waste Management System Management & Operating Contractor) 2000. *CSNF Waste Form Degradation: Summary Abstraction.* ANL-EBS-MD-000015 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000121.0161.

144128 CRWMS M&O 2000. *Design Analysis for UCF Waste Packages*. ANL-UDC-MD-000001 REV 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000526.0336.

144132 CRWMS M&O 2000. *Design analysis for the Naval SNF Waste Package*. ANL-VDC-MD-000001 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000615.0029.

146106 CRWMS M&O 2000. *Design Analysis for the Ex-Container Components*. ANL-XCS-ME-000001 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000525.0374.

147268 CRWMS M&O 2000. *Defense High Level Waste Disposal Container System Description Document*. SDD-DDC-SE-000001 REV 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000823.0001.

147269 CRWMS M&O 2000. *Uncanistered Spent Nuclear Fuel Disposal Container System Description Document*. SDD-UDC-SE-000001 REV 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000822.0004.

148384 CRWMS M&O 2000. *Total System Performance Assessment (TSPA) Model for Site Recommendation.* MDL-WIS-PA-000002 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001226.0003.

150321 Neuman, S.P. 1975. "Analysis of Pumping Test Data from Anisotropic Unconfined Aquifers Considering Delayed Gravity Response." *Water Resources Research, 11,* (2), 329-342. Washington, D.C.: American Geophysical Union. TIC: 222414.

150657 CRWMS M&O 2000. *Performance Confirmation Plan.* TDR-PCS-SE-000001 REV 01 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000601.0196.

150823 CRWMS M&O 2000. *Design analysis for the Defense High-Level Waste disposal Container*. ANL-DDC-ME-000001 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000627.0254.

151550 CRWMS M&O 2000. *Aging and Phase Stability of Waste Package Outer Barrier.* ANL-EBS-MD-000002 REV 00 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20010926.0007.

151568 CRWMS M&O 2000. *Environment on the Surfaces of the Drip Shield and Waste Package Outer Barrier.* ANL-EBS-MD-000001 REV 00 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001219.0080.

151662 CRWMS M&O 2001. *Clad Degradation–Summary and Abstraction*. ANL-WIS-MD-000007 REV 00 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20010214.0229.

151957 Stuckless, J.S. 2000. Archaeological Analogues for Assessing the Long-Term Performance of a Mined Geologic Repository for High-Level Radioactive Waste. Open-File Report 00-181. Denver, Colorado: U.S. Geological Survey. ACC: MOL.20000822.0366.

151965 CRWMS M&O 2000. *Monitored Geologic Repository Test & Evaluation Plan.* TDR-MGR-SE-000010 REV 03. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000926.0296.

152104 CRWMS M&O 2000. *Waste Package Operations Fabrication Process Report.* TDR-EBS-ND-000003 REV 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000927.0002.

152248 BSC (Bechtel SAIC Company) 2001. *Flow of Water and Pooling in a Waste Package.* ANL-EBS-MD-000055 REV 00. Las Vegas, Nevada: Bechtel SAIC Company. ACC: MOL.20010604.0218.

152446 ICRP 1996. *Age-Dependent Doses to Members of the Public from Intake of Radionuclides: Part 5 Compilation of Ingestion and Inhalation Dose Coefficients.* Volume 26, No. 1 of *Annals of the ICRP*. Smith, H., ed.. ICRP Publication 72. New York, New York: Pergamon Press. TIC: 235870.

152985 DOE 2001. *Supplement to the Draft Environmental Impact Statement for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada.* DOE/EIS-0250D-S. Washington, D.C.: U.S. Department of Energy, Office of Civilian Radioactive Waste Management. ACC: MOL.20010524.0184.

153246 CRWMS M&O 2000. *Total System Performance Assessment for the Site Recommendation.* TDR-WIS-PA-000001 REV 00 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001220.0045.

153255 DOE 2001. *Analysis of the Total System Life Cycle Cost of the Civilian Radioactive Waste Management Program.* DOE/RW-0533. Washington, D.C.: U.S. Department of Energy, Office of Civilian Radioactive Waste Management. ACC: MOL.20010802.0217.

153257 DOE 2001. *Nuclear Waste Fund Fee Adequacy: An Assessment.* DOE/RW-0534. Washington, D.C.: U.S. Department of Energy, Office of Civilian Radioactive Waste Management. ACC: MOV.20010607.0015.

153564 BSC 2001. *Disposable Canister Waste Acceptance Criteria.* CAL-WPS-SE-000007 REV 00. Las Vegas, Nevada: Bechtel SAIC Company. ACC: MOL.20010828.0004.

153752 BSC 2001. *Dose Rate Calculation for the 21-PWR UCF Waste Package*. CAL-UDC-NU-000002 REV 01. Las Vegas, Nevada: Bechtel SAIC Company. ACC: MOL.20010627.0027.

153753 BSC 2001. *Dose Rate Calculation for the 44-BWR UCF Waste Package*. CAL-UDC-NU-000003 REV 01. Las Vegas, Nevada: Bechtel SAIC Company. ACC: MOL.20010629.0077.

153755 BSC 2001. *Internal Pressurization Due to Fuel Rod Rupture in Waste Packages*. CAL-EBS-ME-000005 REV 01. Las Vegas, Nevada: Bechtel SAIC Company. ACC: MOL.20010629.0076.

153849 DOE 2001. *Yucca Mountain Science and Engineering Report*. DOE/RW-0539. [Washington, D.C.]: U.S. Department of Energy, Office of Civilian Radioactive Waste Management. ACC: MOL.20010524.0272.

154136 Curry, P.M. 2001. *Monitored Geologic Repository Project Description Document.* TDR-MGR-SE-000004 REV 02 ICN 02. Las Vegas, Nevada: Bechtel SAIC Company. ACC: MOL.20010628.0224.

154138 YMP (Yucca Mountain Site Characterization Project) 2001. *Yucca Mountain Site Characterization Project Requirements Document (YMP-RD).* YMP/CM-0025, Rev. 4, DCN 01. Las Vegas, Nevada: Yucca Mountain Site Characterization Office. ACC: MOL.20010702.0086.

154287 Gardner, D. 2000. "Meeting Summary, NRC/DOE Technical Exchange on Structural Deformation and Seismicity KTI, October 11-12, 2000." E-mail from D. Gardner to C. Hanlon, October 13, 2000, with attachment. ACC: MOL.20001102.0041; MOL.20001102.0042.

154431 BSC 2001. *Dissolved Concentration Limits for Certain Radioactive Elements*. CAL-WIS-MD-000012 REV 00. Las Vegas, Nevada: Bechtel SAIC Company. ACC: MOL.20010806.0071.

154503 Dobson, P.; Hulen, J.; Kneafsey, T.J.; and Simmons, A. 2001. "Permeability at Yellowstone: A Natural Analog for Yucca Mountain Processes." *"Back to the Future – Managing the Back End of the Nuclear Fuel Cycle to Create a More Secure Energy Future," Proceedings of the 9th International High-Level Radioactive Waste Management Conference (IHLRWM), Las Vegas, Nevada, April 29-May 3, 2001.* La Grange Park, Illinois: American Nuclear Society. TIC: 247873.

154547 Dobson, P.; Hulen, J.; Kneafsey, T.J.; and Simmons, A. 2001. "The Role of Lithology and Alteration on Permeability and Fluid Flow in the Yellowstone Geothermal System, Wyoming." *Proceedings, Twenty-Sixth Workshop on Geothermal Reservoir Engineering, Palo Alto, California, January 29-31, 2001*. Workshop Report SGP-TR-168. Stanford, California: Stanford University. TIC: 249825.

154549 BSC 2001. *Thermal Management Analysis for Lower Temperature Designs*. ANL-SFS-MG-000005 REV 00. Las Vegas, Nevada: Bechtel SAIC Company. ACC: MOL.20010814.0329.

154553 BSC 2001. *Gantry Structural/Control System Analysis*. ANL-WER-MD-000001 REV 00. Las Vegas, Nevada: Bechtel SAIC Company. ACC: MOL.20010425.0003.

154554 BSC 2001. *Lower-Temperature Subsurface Layout and Ventilation Concepts.* ANL-WER-MD-000002 REV 00. Las Vegas, Nevada: Bechtel SAIC Company. ACC: MOL.20010718.0225.

154659 BSC 2001. *FY01 Supplemental Science and Performance Analyses, Volume 2: Performance Analyses.* TDR-MGR-PA-000001 REV 00. Las Vegas, Nevada: Bechtel SAIC Company. ACC: MOL.20010724.0110.

154677 BSC 2001. *Drift-Scale Coupled Processes (DST and THC Seepage) Models.* MDL-NBS-HS-000001 REV 01 ICN 01. Las Vegas, Nevada: Bechtel SAIC Company. ACC: MOL.20010418.0010.

154704 EDCON 2000. *Report for the Borehole Gravity Survey in the NC-EWDP-19D Well in Nye County, Nevada on Behalf of TRW Corp.* EDCON Job #00011. Denver, Colorado: EDCON, Inc. TIC: 249823.

154724 Paces, J.B. and Whelan, J.F. 2001. "Water-Table Fluctuations in the Amargosa Desert, Nye County, Nevada." *"Back to the Future – Managing the Back End of the Nuclear Fuel Cycle to Create a More Secure Energy Future," Proceedings of the 9th International High-Level Radioactive Waste Management Conference (IHLRWM), Las Vegas, Nevada, April 29-May 3, 2001.* La Grange Park, Illinois: American Nuclear Society. TIC: 247873.

154773 Whelan, J.F., Roedder, E., and Paces, J.B. 2001. "Evidence for an Unsaturated-Zone Origin of Secondary Minerals in Yucca Mountain, Nevada." *High Level Radioactive Waste Management: Proceedings of the Ninth International Conference, April 29 – May 3, 2001, Las Vegas, Nevada* [CD-ROM]. La Grange Park, Illinois: American Nuclear Society. TIC: 247873.

154826 BSC 2001. *Features, Events, and Processes in UZ Flow and Transport.* ANL-NBS-MD-000001 REV 01. Las Vegas, Nevada: Bechtel SAIC Company. ACC: MOL.20010423.0321.

154844 BSC 2001. *Secondary Uranium-Phase Paragenesis and Incorporation of Radionuclides into Secondary Phases.* ANL-EBS-MD-000019 REV 00 ICN 01. Las Vegas, Nevada: Bechtel SAIC Company. ACC: MOL.20010625.0306.

154857 BSC 2001. *Preliminary Preclosure Safety Assessment for Monitored Geologic Repository Site Recommendation*. TDR-MGR-SE-000009 REV 00 ICN 03. Las Vegas, Nevada: Bechtel SAIC Company. ACC: MOL.20010705.0172.

154951 CRWMS M&O 2001. *Repository Safety Strategy: Plan to Prepare the Safety Case to Support Yucca Mountain Site Recommendation and Licensing Considerations*. TDR-WIS-RL-000001 REV 04 ICN 01. Two volumes. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20010329.0825.

155187 BSC 2001. *Ground Control for Emplacement Drifts for SR*. ANL-EBS-GE-000002 REV 00 ICN 01. Las Vegas, Nevada: Bechtel SAIC Company. ACC: MOL.20010627.0028.

155217 BSC 2001. *Tip-Over of 12-PWR and 24-BWR Waste Packages*. CAL-UDC-ME-000016 REV 00. Las Vegas, Nevada: Bechtel SAIC Company. ACC: MOL.20010425.0023.

155329 BSC 2001. *Dose Rate Calculation for the Codisposal Waste Package of HLW Glass and the Melt-Dilute Al SNF*. CAL-DDC-NU-000004 REV 00. Las Vegas, Nevada: Bechtel SAIC Company. ACC: MOL.20010730.0063.

155455 BSC 2001. *Summary of Dissolved Concentration Limits*. ANL-WIS-MD-000010 REV 01, ICN 01. Las Vegas, Nevada: Bechtel SAIC Company. ACC: MOL.20010702.0085.

155638 BSC 2001. *EBS Radionuclide Transport Abstraction.* ANL-WIS-PA-000001 REV 00 ICN 03. Las Vegas, Nevada: Bechtel SAIC Company. ACC: MOL.20010806.0076.

155640 BSC 2001. *Environment on the Surfaces of the Drip Shield and Waste Package Outer Barrier.* ANL-EBS-MD-000001 REV 00 ICN 02. Las Vegas, Nevada: Bechtel SAIC Company. ACC: MOL.20010724.0082.

155661 BSC 2001. *Naval Spent Nuclear Fuel Disposal Container System Description Document.* SDD-VDC-SE-000001 REV 01 ICN 01. Las Vegas, Nevada: Bechtel SAIC Company. ACC: MOL.20010927.0075.

155667 BSC 2001. *Longevity of Emplacement Drift Ground Support Materials.* ANL-EBS-GE-000003 REV 01 ICN 01. Las Vegas, Nevada: Bechtel SAIC Company. ACC: MOL.20010613.0246.

155696 Peterman, Z.E. and Cloke, P.L. 2001. "Geochemical Homogeneity of Tuffs at the Potential Repository Level, Yucca Mountain, Nevada." *"Back to the Future – Managing the Back End of the Nuclear Fuel Cycle to Create a More Secure Energy Future," Proceedings of the 9th International High-Level Radioactive Waste Management Conference (IHLRWM), Las Vegas, Nevada, April 29-May 3, 2001*. La Grange Park, Illinois: American Nuclear Society. TIC: 247873.

155718 BSC 2001. *Lower Temperature Invert Design for Diffusion Barrier*. ANL-EDS-ST-000001 REV 00. Las Vegas, Nevada: Bechtel SAIC Company, LLC. ACC: MOL.20010814.0328.

155734 DOE 2001. *Yucca Mountain Preliminary Site Suitability Evaluation.* DOE/RW-0540. Washington, D.C.: U.S. Department of Energy, Office of Civilian Radioactive Waste Management. ACC: MOL.20011101.0082.

155747 BSC 2001. *Tip-Over of the 5 DHLW/DOE SNF – Long Waste Package Containing Fort Saint Vrain HTGR Fuel Onto an Unyielding Surface.* CAL-DDC-ME-000006 REV 00. Las Vegas, Nevada: Bechtel SAIC Company. ACC: MOL.20011008.0001.

155748 BSC 2001. *Thermal Evaluation of the Fort Saint Vrain Codisposal Waste Package*. CAL-WIS-TH-000012 REV 00. Las Vegas, Nevada: Bechtel SAIC Company. ACC: MOL.20010718.0263.

155749 BSC 2001. *Dose Rate Calculation for the Codisposal Waste Package of HLW Glass and the FSVR Fuel*. CAL-DDC-NU-000003 REV 00. Las Vegas, Nevada: Bechtel SAIC Company. ACC: MOL.20010924.0044.

155809 BSC 2001. *Microbial Transport Sensitivity Calculations*. CAL-EBS-PA-000011 REV 00. Las Vegas, Nevada: Bechtel SAIC Company. ACC: MOL.20011015.0024.

155810 BSC 2001. *In-Drift Microbial Communities Model Validation Calculations*. CAL-EBS-EV-000001 REV 00. Las Vegas, Nevada: Bechtel SAIC Company. ACC: MOL.20011016.0044.

155839 Padula, D. 2001. "Design Dose Rate." Memorandum from D. Padula (BSC) to M. Iyer, May 15, 2001, PROJ.05/01.030, with enclosures. ACC: MOL.20010815.0155.

155950 BSC 2001. *FY01 Supplemental Science and Performance Analyses, Volume 1: Scientific Bases and Analyses*. TDR-MGR-MD-000007 REV 00 ICN 01. Las Vegas, Nevada: Bechtel SAIC Company. ACC: MOL.20010801.0404; MOL.20010712.0062; MOL.20010815.0001.

155974 BSC 2001. *Calibration of the Site-Scale Saturated Zone Flow Model*. MDL-NBS-HS-000011 REV 00 ICN 01. Las Vegas, Nevada: Bechtel SAIC Company. ACC: MOL.20010713.0049.

155982 DOE 2001. *Site Characterization Progress Report: Yucca Mountain, Nevada.* Number 23. [Washington, D.C.]: U.S. Department of Energy, Office of Civilian Radioactive Waste Management. ACC: MOL.20010412.0099.

156062 BSC 2001. *Gamma and Neutron Radiolysis in the 21-PWR Waste Package*. CAL-MGR-NU-000006 REV 00. Las Vegas, Nevada: Bechtel SAIC Company. ACC: MOL.20010522.0198.

156276 BSC 2001. *Repository Multiple Waste Package Thermal Calculation*. CAL-WIS-TH-000010 REV 00. Las Vegas, Nevada: Bechtel SAIC Company. ACC: MOL.20010814.0330.

156277 BSC 2001. *Symmetric Rock Fall on Waste Package.* CAL-EBS-ME-000009 REV 00. Las Vegas, Nevada: Bechtel SAIC Company. ACC: MOL.20010815.0270.

156304 BSC 2001. *Drift Degradation Analysis.* ANL-EBS-MD-000027 REV 01 ICN 01. Las Vegas, Nevada: Bechtel SAIC Company. ACC: MOL.20011029.0311.

156324 BSC 2001. *Geochemistry Model Validation Report: External Accumulation Model*. ANL-EBS-GS-000002 REV 00. Las Vegas, Nevada: Bechtel SAIC Company. ACC: MOL.20011008.0005.

156332 Crump, T. 2001. "Igneous Activity TE Meeting Summary." E-mail from T. Crump to J. McNeish, June 25, 2001, with attachment. ACC: MOL.20010723.0094; MOL.20010723.0095.

156356 BSC 2001. *Degradation of Stainless Steel Structural Material.* ANL-EBS-MD-000007 REV 00 ICN 01. Las Vegas, Nevada: Bechtel SAIC Company. ACC: MOL.20010713.0048.

156424 BSC 2001. *Subsurface Shielding Source Term Specification Calculation*. CAL-WER-NU-000003 REV 00. Las Vegas, Nevada: Bechtel SAIC Company. ACC: MOL.20010423.0323.

156460 BSC 2001. *Total System Performance Assessment – Analyses for Disposal of Commercial and DOE Waste Inventories at Yucca Mountain – Input to Final Environmental Impact Statement and Site Suitability Evaluation.* REV 00 ICN 01. Las Vegas, Nevada: Bechtel SAIC Company. ACC: MOL.20011114.0246.

156472 Krier, D. 2001. "Meeting Summary Igneous Activity Tech Exchange." E-mail from D. Krier to J. Burford, September 7, 2001, with attachments. ACC: MOL.20010914.0199.

156474 NWTRB (U.S. Nuclear Waste Technical Review Board) 2001. *Report to the U.S. Congress and the Secretary of Energy, January to December 2000.* Arlington, Virginia: U.S. Nuclear Waste Technical Review Board. TIC: 249900.

156507 Paces, J.B.; Neymark, L.A.; Marshall, B.D.; Whelan, J.F.; and Peterman, Z.E. 2001. *Ages and Origins of Calcite and Opal in the Exploratory Studies Facility Tunnel, Yucca Mountain, Nevada*. Water-Resources Investigations Report 01-4049. Denver, Colorado: U.S. Geological Survey. TIC: TBD.

156564 BSC 2001. *Shaft Siting and Configuration for Flexible Operating Mode*. ANL-SFS-MG-000006 REV 00. Las Vegas, Nevada: Bechtel SAIC Company. ACC: MOL.20010814.0327.

156700 BSC 2001. *Invert Diffusion Properties Model.* ANL-EBS-MD-000031 REV 01 ICN 01. Las Vegas, Nevada: Bechtel SAIC Company. ACC: MOL.20010801.0315.

156745 Dobson, D.A. 2001. "Submittal of Final Version of the DST Bulkhead White Paper." E-mail from D.A. Dobson to R. Wagner, April 26, 2001, with attachment. ACC: MOL.20010706.0028.

156784 BSC 2001. *Drop Calculations of HLW Canister and Pu Can-in-Canister*. CAL-EBS-ME-000015 REV 00. Las Vegas, Nevada: Bechtel SAIC Company. ACC: MOL.20010809.0069.

156785 BSC 2001. *Natural Convection Calculation of Waste Package Drift Emplacement.* CAL-EBS-TH-000001 REV 00. Las Vegas, Nevada: Bechtel SAIC Company. ACC: MOL.20011008.0004.

156786 BSC 2001. *Radiolytic Production of Nitric Acid on the Radial Surface of the 21-PWR Waste Package.* CAL-MGR-NU-000007 REV 00. Las Vegas, Nevada: Bechtel SAIC Company. ACC: MOL.20010731.0055.

156787 BSC 2001. *Radiolytic Specie Generation from Internal Waste Package Criticality*. CAL-EBS-NU-000017 REV 00. Las Vegas, Nevada: Bechtel SAIC Company. ACC: MOL.20011017.0090.

156789 Brownson, D. 2001. *Waste Package Design Methodology Report*. TDR-MGR-MD-000006 REV 01. Las Vegas, Nevada: Bechtel SAIC Company. ACC: MOL.20011016.0045.

156790 BSC 2001. *Geochemistry Model Validation Report: Material Degradation and Release Model*. ANL-EBS-GS-000001 REV 00. Las Vegas, Nevada: Bechtel SAIC Company. ACC: MOL.20011017.0091.

156791 BSC 2001. *Waste Package Tip-Over of Naval SNF Long*. CAL-VDC-ME-000004 REV 00. Las Vegas, Nevada: Bechtel SAIC Company. ACC: MOL.20010905.0135.

156792 BSC 2001. *Waste Form, Heat Output, and Waste Package Spacing for an Idealized Drift Segment*. CAL-EBS-MD-000019 REV 00. Las Vegas, Nevada: Bechtel SAIC Company. ACC: MOL.20010724.0078.

156793 Knapp, M.C. 2001. *Waste Package Project FY-01 Closure Methods Report*. TDR-EBS-ND-000006 REV 00. Las Vegas, Nevada: Bechtel SAIC Company. ACC: MOL.20011004.0134.

156794 BSC 2001. *Horizontal Lifting of 5 DHLW/DOE-Long, 12-PWR Long and 24-BWR Waste Packages*. CAL-EBS-ME-000010 REV 00. Las Vegas, Nevada: Bechtel SAIC Company. ACC: MOL.20010530.0143.

156795 BSC 2001. *Static Loading of a Waste Package on an Uneven Emplacement Pallet*. CAL-UDC-ME-000015 REV 00. Las Vegas, Nevada: Bechtel SAIC Company. ACC: MOL.20010606.0323.

156796 BSC 2001. *Swing-Down of 21-PWR Waste Package.* CAL-UDC-ME-000013 REV 00. Las Vegas, Nevada: Bechtel SAIC Company. ACC: MOL.20010521.0062.

156797 BSC 2001. *Tensile Stresses Developing in an Outer Shell of a Waste Package Mounted on Emplacement Pallet*. CAL-EBS-ME-000004 REV 01. Las Vegas, Nevada: Bechtel SAIC Company. ACC: MOL.20010820.0144.

156798 BSC 2001. *Vertical Drop of 5 DHLW/DOE SNF Long Waste Package*. CAL-DDC-ME-000005 REV 00. Las Vegas, Nevada: Bechtel SAIC Company. ACC: MOL.20010702.0149.

156799 BSC 2001. *Waste Package Tip-Over of 5-DHLW/DOE SNF Short*. CAL-DDC-ME-000004 REV 00. Las Vegas, Nevada: Bechtel SAIC Company. ACC: MOL.20010105.0015.

156800 Plinski, M.J. 2001. *Waste Package Operations Fabrication Process Report*. TDR-EBS-ND-000003 REV 02. Las Vegas, Nevada: Bechtel SAIC Company. ACC: MOL.20011003.0025.

156801 BSC 2001. *Lid Lifting Feature Structural Calculation*. CAL-EBS-ME-000014 REV 00. Las Vegas, Nevada: Bechtel SAIC Company. ACC: MOL.20010824.0009.

156803 BSC 2001. *Overall Subsurface Ventilation System*. ANL-SVS-HV-000002 REV 00 ICN 02. Las Vegas, Nevada: Bechtel SAIC Company. ACC: MOL.20010718.0264.

156805 BSC 2001. *Defense High Level Waste Glass Degradation*. ANL-EBS-MD-000016 REV 00 ICN 02. Las Vegas, Nevada: Bechtel SAIC Company. ACC: MOL.20011015.0502.

156806 BSC 2001. *Effect of Waste Package Materials Surface Area and High-Level Waste Glass Reaction Rate on In-Package Chemistry.* CAL-EBS-MD-000020 REV 00. Las Vegas, Nevada: Bechtel SAIC Company. ACC: MOL.20010814.0326.

156807 BSC 2001. *Plugging of Stress Corrosion Cracks by Precipitates*. CAL-EBS-MD-000017. Las Vegas, Nevada: Bechtel SAIC Company. ACC: MOL.20011010.0168.

156880 Dickerson, R.P. 2001. "Hydrogeologic Characteristics of Faults at Yucca Mountain, Nevada." *"Back to the Future – Managing the Back End of the Nuclear Fuel Cycle to Create a More Secure Energy Future," Proceedings of the 9th International High-Level Radioactive Waste Management Conference (IHLRWM), Las Vegas, Nevada, April 29-May 3, 2001.* La Grange Park, Illinois: American Nuclear Society. TIC: 247873.

156881 LeCain, G.D. and Kurzmack, M. 2001. "Use of Thermal Data to Estimate Infiltration, Yucca Mountain, Nevada." *High Level Radioactive Waste Management : Proceedings of the Ninth International Conference, April 29 – May 3, 2001, Las Vegas, Nevada* [CD-ROM]. La Grange Park, Illinois: American Nuclear Society. TIC: 247873.

156884 Yang, I.C. 2001. "Pore-Water Isotopic Compositions and Unsaturated-Zone Flow, Yucca Mountain, Nevada." *"Back to the Future – Managing the Back End of the Nuclear Fuel Cycle to Create a More Secure Energy Future," Proceedings of the 9th International High-Level Radioactive Waste Management Conference (IHLRWM), Las Vegas, Nevada, April 29-May 3, 2001.* La Grange Park, Illinois: American Nuclear Society. TIC: 247873.

156889 Neymark, L.A.; Amelin, Y.V.; Paces, J.B.; Peterman, Z.E.; and Whelan, J.F. 2001. "Age Constraints on Fluid Inclusions in Calcite at Yucca Mountain." *"Back to the Future – Managing the Back End of the Nuclear Fuel Cycle to Create a More Secure Energy Future," Proceedings of the 9th International High-Level Radioactive Waste Management Conference (IHLRWM), Las Vegas, Nevada, April 29, May 3, 2001.* La Grange Park, Illinois: American Nuclear Society. TIC: 247873.

156890 Cohon, J.L. 2001. Response to DOE Presentations and its Yucca Mountain Project Contractor Team at the May 8 and 9, 2001 Meeting, in Arlington, Virginia. Letter from J.L. Cohon (NWTRB) to L. Barrett (DOE/OCRWM), July 17, 2001. ACC: MOL.20020423.0310.

156934 BSC 2001. *Hydrogen Induced Cracking of Drip Shield.* ANL-EBS-MD-000006 REV 00 ICN 02. Las Vegas, Nevada: Bechtel SAIC Company. ACC: MOL.20010724.0081.

156936 BSC 2001. *Abstraction of Models for Pitting and Crevice Corrosion of Drip Shield and Waste Package Outer Barrier.* ANL-EBS-PA-000003 REV 00 ICN 01. Las Vegas, Nevada: Bechtel SAIC Company. ACC: MOL.20010926.0008.

156955 BSC 2001. *Significant Radionuclides Determination.* CAL-WHS-SE-000002 REV 00. Las Vegas, Nevada: Bechtel SAIC Company. ACC: MOL.20010905.0143.

156956 BSC 2001. *Canister Transfer System Event Sequence Calculation.* CAL-CTS-SE-000001 REV 00. Las Vegas, Nevada: Bechtel SAIC Company. ACC: MOL.20010905.0142.

156957 BSC 2001. *DOE SNF BDBE Dose Calculations.* CAL-WPS-SE-000006 REV 00. Las Vegas, Nevada: Bechtel SAIC Company. ACC: MOL.20010625.0305.

156965 BSC 2001. *Probability Distribution for Flowing Interval Spacing.* ANL-NBS-MD-000030 REV 00 ICN 02. Las Vegas, Nevada: Bechtel SAIC Company. ACC: MOL.20010625.0304.

156977 Meserve, R.A. 2001. NRC Preliminary Sufficiency Comments. Letter from NRC Chairman R.A. Meserve to DOE Under-Secretary Card, November 13, 2001. MOL.20020108.0128.

159350 Cohon, J.L. 2001. Comments on April 13, 2001, Meeting on Developing Multiple Lines of Evidence. Letter from J.L. Cohon (NWTRB) to L. Barrett (DOE/OCRWM), June 11, 2001. ACC: MOL.20020812.0317.

7.2 CODES, STANDARDS, AND REGULATIONS

100017 Energy Policy Act of 1992. Public Law No. 102–486. 106 Stat. 2776. Readily available.

101680 64 FR 8640. Disposal of High-Level Radioactive Wastes in a Proposed Geologic Repository at Yucca Mountain, Nevada. Proposed rule 10 CFR 63. Readily available.

101681 Nuclear Waste Policy Act of 1982. 42 U.S.C. 10101 et seq. Readily available.

103537 10 CFR 2. Energy: Rules of Practice for Domestic Licensing Proceedings and Issuance of Orders. Readily available.

104787 10 CFR 20. Energy: Standards for Protection Against Radiation. Readily available.

105065 64 FR 46976. Environmental Radiation Protection Standards for Yucca Mountain, Nevada. Proposed 40 CFR 197. Readily available.

124754 64 FR 67054. Office of Civilian Radioactive Waste Management; General Guidelines for the Recommendation of Sites for Nuclear Waste Repositories; Yucca Mountain Site Suitability Guidelines. Proposed rule 10 CFR Part 963. Readily available.

155009 66 FR 23013. Office of Civilian Radioactive Waste Management; Yucca Mountain Science and Engineering Report; Site Recommendation Consideration and Request for Comment. Readily available.

155216 66 FR 32074. 40 CFR Part 197, Public Health and Environmental Radiation Protection Standards for Yucca Mountain, NV; Final Rule. Readily available.

155238 40 CFR 197. Protection of Environment: Public Health and Environmental Radiation Protection Standards for Yucca Mountain, Nevada. Readily available.

156605 10 CFR 63. Energy: Disposal of High-Level Radioactive Wastes in a Geologic Repository at Yucca Mountain, Nevada. Readily available.

156671 66 FR 55732. Disposal of High-Level Radioactive Wastes in a Proposed Geologic Repository at Yucca Mountain, NV. Final Rule 10 CFR Part 63. Readily available.

156908 66 FR 57298. Office of Civilian Radioactive Waste Management; General Guidelines for the Recommendation of Sites for Nuclear Waste Repositories; Yucca Mountain Site Suitability Guidelines. Final Rule 10 CFR Part 963. Readily available.

156969 66 FR 43850. Office of Civilian Radioactive Waste Management, Site Recommendation Consideration Hearings and End of Public Comment Period; Yucca Mountain Preliminary Site Suitability Evaluation. Readily available.

156972 66 FR 50176. Office of Civilian Radioactive Waste Management: Site Recommendation Consideration Process; Las Vegas Science Center To Serve as Extended Hearing Facility. Readily available.

156973 66 FR 51027. Office of Civilian Radioactive Waste Management, Site Recommendation Consideration Process-Further Extension of Public Comment Period. Readily available.

156976 66 FR 57049. Office of Civilian Radioactive Waste Management; Site Recommendation Consideration Process-Announcement of Supplemental Public Comment Period. Readily Available.

157061 66 FR 49372. Office of Civilian Radioactive Waste Management; Site Recommendation Consideration Hearings; Yucca Mountain – Announcement of Changes in Public Hearings. Readily available.

157062 66 FR 58460. Office of Civilian Radioactive Waste Management; Site Recommendation Consideration Process-Announcement of Public Hearings on Supplemental Information. Readily available.

157159 66 FR 50423. Office of Civilian Radioactive Waste Management Site Recommendation Consideration Process – Public Hearing Sessions in Various Localities To Receive Comments on Yucca Mountain Site Recommendation Consideration. Readily available.

7.3 SOURCE DATA, LISTED BY DATA TRACKING NUMBER

154686 MO0007NYE02565.024. Cuttings Sample Log for Borehole NC-EWDP-19D. Submittal date: 07/11/2000.

APPENDIX A

LIST OF COMPLETED YUCCA MOUNTAIN SITE CHARACTERIZATION PROJECT DELIVERABLES

INTENTIONALLY LEFT BLANK

Table A-1. List of Completed Yucca Mountain Site Characterization Project Deliverables (April 1, 2001, to September 30, 2001)

Document Control Number	Deliverable Number	Title and Revision
26500	SSJ1032M3	Comment Response Document to the Environmental Impact Statement for a Geological Repository for the Disposal of Spent Nuclear and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada
28519	RPC194M3	Gantry Structural/Control System Analysis
28612	SLC1045M3	FY01 Supplemental Science and Performance Analyses, Volume 1, Scientific Bases and Analyses
28613	SL924M3	FY01 Supplemental Science and Performance Analyses, Volume 2, Performance Analyses
28755	SETA09M3	Technical Analysis, TBX Resolution and Technical Issue Resolution Activities Semi-Annual Status Report
28765	SLT002M3	Second Quarter Status of Data Submittals and Incorporation into the Technical Data Management System
28858	SETA11M3	Preliminary ISA Status Report
28863	BMK15M3	OMB Circular A-11 Exhibit 53 Information
28964	RPC906M3	Surface Facilities EIS Letter Report
29048	SC0080M3	Busted Butte Closure Plan
29054	WP065M3	Waste Package Operations Fabrication Process Report
29056	SSH014M3	Annual Training Plan
29057	SSH015M3	Occupational Training Needs Assessment
29072	SCC1462M3	Noise Abatement Plan
29107	SSG10M3	Bechtel SAIC, LLC Annual Training Plan Document FY 02 Bechtel SAIC, LLC Annual Training Needs Assessment
29130	SLT003M3	Data Submittals and Incorporation into the Technical Data Management System
29220	SSG11M3	Bechtel SAIC, LLC Annual Training Needs Assessment
29235	SLCTS4M3	CIRS Semi-Annual Status Report (SLCTS4M3)
29274	SLPS0035M3	Advance Copies of PSSE Available in DC
29285	SLC155M3	Software Requirements for the Quality Assurance Interface with the Integrated Issues
29287	SLSR0035M3	S&ER Advanced Copies Available in DC
29348	BMF00BM3	Initial FY02 YMP Plan Update to YMSCL
29461	SEPRJMM3	Site Characterization Progress Report Number 24
29476	WP066M3	Waste Package Project FY-01 Closure Methods Report
29577	SL986M3	FEIS & SSE TASP Final Report
29684	SLT004M3	Data Submittals and Incorporation into the Technical Data Management System
29789	BMF00CM3	Annual Plan Update (FY02-LA Detailed Work Plan)

INTENTIONALLY LEFT BLANK

APPENDIX B

LIST OF FUTURE YUCCA MOUNTAIN SITE CHARACTERIZATION PROJECT DELIVERABLES AND STATUS OF WORK IN PROGRESS

INTENTIONALLY LEFT BLANK

Table B-1. List of Future Project Documents Shown as "In Progress" in This Report

Work in Progress Number	Document, Deliverable, or Activity ID Number	Proposed Title	Expected Completion Date
1	DOE/RW-0552	Progress Report No. 24	03/14/02 Actual
2	SFC1020M3	MGR Site Development Plan	10/31/02
3	DOE/RW-0459	Yucca Mountain Site Suitability Evaluation	12/10/01 Actual
4	DOE/EIS-0250	Final Environmental Impact Statement for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada	02/14/02 Actual
5	DOE/RW-0539-1	Yucca Mountain Science and Engineering Report, Rev. 1	02/14/02 Actual
6	DOE/RW-0548	SR Comment Summary Document	02/14/02 Actual
7	B00000000-01717-5700-00021	Documentation of Program Change, REV 04, ICN 01	02/19/02 Actual
8	ANL-WHS-SE-000002	Commercial SNF Accident Release Fractions, REV 01	09/02
9	ANL-NBS-GS-000008	Future Climate Analysis	10/12/01 Actual

Table B-2. Status of Project Documents Shown as "In Progress" in Previous Progress Reports

Work in Progress Number	Document, Deliverable, Or Activity ID Number	Proposed Title	Expected Completion Date
PR-24 Listings			
2	SLPS190M3	Preliminary Site Suitability Evaluation	07/01 Actual
4	SLSRV2M3	FY01 Supplemental Science and Performance Analyses: Volume 1 Volume 2	 06/01 Actual 07/01 Actual
5	DOE/RW-0351	Rev. 4 of the Waste Acceptance System Requirements Document	01/02 Actual
PR 20 Listings			
10	SA10B315	Submit Seismic Topical Report (STR) III for QAP 6.2/ YAP-30.12 Reviews	Deferred until 3/04

INTENTIONALLY LEFT BLANK

APPENDIX C

GLOSSARY

INTENTIONALLY LEFT BLANK

APPENDIX C

GLOSSARY

NOTE: Many of the following definitions are Yucca Mountain Site Characterization Project-specific.

Glossary Item	Definition or Explanation
Alcove	Underground excavations made to the sides of drifts or ramps of the Exploratory Studies Facility (ESF) or Enhanced Characterization of the Repository Block (ECRB) Cross Drift and used as sites for in situ testing of ambient rock characteristics or thermal perturbations of those characteristics.
Alluvium	Unconsolidated soil and rock fragments deposited by the action of rivers, and sometimes the term alluvium is used loosely to refer to all valley-fill material, which is unconsolidated rock fragments derived from the erosion of the bordering mountains.
Analysis and Model Report	A report that documents the technical underpinnings used to defend the applicability of the model for its intended purpose of evaluating the postclosure performance of the potential Yucca Mountain Repository System.
Aquifer	A water-bearing layer of permeable rock that is capable of yielding groundwater to supply wells and springs.
Backfill	Material placed in the emplacement drifts to refill the drift after WPs are placed in the drift and prior to closing the repository.
Borehole	A hole bored or drilled to investigate subsurface features.
Characterization	A study done to investigate (i.e., to determine the character or quality) and describe an item or process.
Colloid	Large molecules or small particles that have at least one dimension within the size range of 10^{-9} to 10^{-6} m, which is suspended in a liquid, such as groundwater. Some radionuclides bind with colloids (either reversibly or irreversibly) and can travel great distances in groundwater. Colloids may form directly from insoluble radionuclides (intrinsic colloids), may form from degraded SNF or glass waste forms (waste form colloids), or may form from other natural or man-made materials with which radionuclides can bind (pseudocolloids).
Cross Drift	The west-southwest trending excavation extending from near the base of the north ramp of the ESF through the main trace of the Solitario Canyon fault.
Design Feature	Enhancements to design that can be easily incorporated within multiple alternative designs.
Drift	Mining terminology for a horizontal underground passage.

Glossary Item	Definition or Explanation
Drip Shield	A sheet of impermeable material placed above a WP to prevent seepage water from dripping onto the WP.
Emplacement Area	That part of the geologic repository in which radioactive waste would be placed.
Engineered Barrier System	Those engineered features of the geologic repository that contribute to containing radioactive wastes and preventing or delaying them from escaping the geologic repository. Engineered barriers are items such as WPs and drip shields.
Fault Zone	An area composed of many small, closely spaced rock fractures that show evidence of movement, or such an area composed of breccia or fault gouge.
Flexible Design	Repository design that provides operational and control flexibility that allows repository operations for various heat loading scenarios by adjusting heat removal ventilation rates and duration so as to limit the maximum postclosure surface temperatures of the WPs and the temperatures in the emplacement drift walls to values that will reduce uncertainty in coupled thermal-hydrological-mechanical-chemical process.
Geologic Repository	A facility designed for underground disposal of spent nuclear fuel and high-level radioactive waste.
Hydraulic Conductivity	A measure of the ability of a soil or rock material to pass water through its connected pores or fractures.
Important to Safety	With reference to structures, systems, and components (SSCs), those engineered features of the geologic repository operations area, whose function is to (1) provide reasonable assurance that high-level waste can be received, handled, packaged, stored, emplaced, and retrieved without exceeding the proposed radiological exposure limit, or (2) prevent or mitigate design basis events that could result in doses equal to or greater than the proposed radiological exposure limit to any individual located on or beyond any point on the boundary of the site.
Key Technical Issues	The ten issues identified by the U.S. Nuclear Regulatory Commission that must be resolved before the nuclear waste repository can be issued a license. Specifically, these issues relate to: Unsaturated Zone, Igneous Activity, Container Life and Source Term, Structural Deformation and Seismicity, Saturated Zone, Radionuclide Transport, Evaluation of the Near Field, Thermal Effects on Flow, Repository Design and Thermal Mechanical Effects, and TSPA Integration.
Longitudinal Dispersivity	A measure of the ability of a soil or rock material to spread a solute moving through it, by elongating the solute plume in the direction of the flow lines.

Glossary Item	Definition or Explanation
Model	A depiction of a system, phenomenon, or process including any hypotheses required to describe the system or explain the phenomenon or process. The depictions may be conceptual or numerical.
Natural Barrier System	Those natural features of the geologic repository that contribute to containing radioactive wastes and preventing or delaying them from leaving the geologic repository. Natural barriers are items such as the rocks above and below the emplacement area.
Near-Field Environment	The zone of environmental conditions that directly impacts the WP container materials and the waste form.
Niche	A relatively shallow excavation in the side of a drift where scientific experiments can be conducted.
Perched Water	Small bodies of water held above the water table and supported by a relatively impermeable layer of rock.
Performance-Based Approach	A requirement that relies on measurable or calculable outcomes, with some flexibility in meeting those outcomes. A performance-based regulatory approach establishes performance and results as the primary basis for regulatory decision-making.
Performance Confirmation	The program of tests, experiments, and analyses that are conducted to evaluate the adequacy of the information used to demonstrate compliance with the performance of objectives of 10 CFR 63.
Permeability	Measurement of the degree to which a given material or substance will permit the passage of air or water.
Porosity	The fraction of the total volume of soil or rock occupied by void spaces. The "effective porosity" is a measure of the fraction of soil or rock occupied by connected void spaces and can be determined from tracer testing.
Postclosure	The time after the repository is closed (contrast with preclosure).
Preclosure	The time before the repository is closed (contrast with postclosure).
Process Model Report	A report that documents a synthesis of the necessary and sufficient technical information that the Project will be relying upon to support its site suitability evaluation and the licensing safety case pertaining to a particular process model.
Quality Assurance	All those planned and systematic actions necessary to provide adequate confidence that the geologic repository and its subsystems or components will perform satisfactorily.

Glossary Item	Definition or Explanation
Recharge	Water that flows into an aquifer and replaces, or recharges, water that is lost from the aquifer by pumping or natural discharge.
Repository Block	The geologic structure (i.e., block of rock) inside of which the emplacement area would be constructed.
Risk-Informed Approach	An approach to regulatory decision-making whereby risk insights (results and findings from risk assessments) and other factors are considered together to establish requirements that focus licensee and regulatory attention on design and operational issues commensurate with their importance to public health and safety.
Repository Horizon	The stratigraphic horizon in which the potential repository might be constructed.
Saturated Zone	The subsurface zone below the water table in which all void space is filled with water at a pressure greater than the pressure of the atmosphere.
Sensitivity Studies	Studies of models to determine the magnitude of differences in the results of the models that result from changes to the input values. These studies determine how sensitive the results of the model are to changes in the inputs and permit researchers to determine the input factors that most affect the results.
Specific Flux	The fraction of the total volume of soil or rock occupied by void spaces. The "effective porosity" is a measure of the fraction of soil or rock occupied by connected void spaces and can be determined from tracer testing.
Sufficiency	"…the preliminary comments of the U.S. Nuclear Regulatory Commission concerning the extent to which the at-depth site characterization analysis and the waste form proposal for Yucca Mountain seem to be sufficient for inclusion in any application to be submitted by the Secretary for licensing of the site as a repository…" (Nuclear Waste Policy Act of 1982, §114(a)(1)(e). The NRC sufficiency comments are required to be included as part of the Site Recommendation package to be submitted by the Secretary to the President.
Transmissivity	The hydraulic conductivity multiplied by the aquifer thickness.
Tuff	Volcanic rock resulting from pyroclastic (explosive) volcanic ash deposits.
Unsaturated Zone	The volume of earth below the ground surface, and above the water table, in which the void space contains water at less than atmospheric pressure and air at atmospheric pressure.
Vitric	Any pyroclastic material containing at least 75 percent glass.

Glossary Item	Definition or Explanation
Waste Form	A generic term that refers to radioactive materials and any encapsulating or stabilizing matrix.
Waste Package	An engineered containment vessel made of corrosion-resistant materials, in which radioactive material can be stored.
Water Table	The top of the saturated zone below which the rocks are saturated with water, and above which the rocks are not saturated (i.e., the interface between the saturated and unsaturated zones).

INTENTIONALLY LEFT BLANK