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NUCLEAR WASTE POLICY ACT
(Section 113)

Site Characterization Progress Report: Yucca Mountain, Nevada

April 1, 1990 - September 30, 1990

Number 3

March 1991

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

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Washington, D.C. 20585

DISCLAIMER

FOREWORD

In accordance with the requirements of Section 113(b)(3) of the Nuclear Waste Policy Act of 1982 (NWPA), as amended, the U.S. Department of Energy (DOE) has prepared this report on the progress of site characterization activities at Yucca Mountain in southern Nevada from April 1, 1990, through September 30, 1990. This progress report is the third of a series of reports that are issued at intervals of approximately six months during site characterization.

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EXECUTIVE SUMMARY

In accordance with the requirements of Section 113(b)(3) of the NWPA, as amended, the DOE has prepared this report on the progress of site characterization activities at Yucca Mountain, Nevada, for the period April 1 through September 30, 1990. This report is the third of a series of reports that are issued at intervals of approximately six months during site characterization. The report covers a number of new initiatives to improve the effectiveness of the site characterization program and covers continued efforts related to preparatory activities, study plans, and performance assessment.

In the fall of 1989, the Secretary of Energy completed a comprehensive reassessment of the waste management program. One of the initiatives that resulted was concerned with management and organization. It included the appointment of a new Office of Civilian Radioactive Waste Management (OCRWM) Director and establishment of direct-line reporting by the manager of the repository project to OCRWM at DOE/Headquarters (DOE/HQ). Following his appointment as OCRWM Director, Dr. John Bartlett initiated a reorganization designed to fulfill the Secretary's initiatives and develop a more strongly goal and action oriented program.

Another of the Secretary's initiatives, all of which are summarized in the Report to Congress on Reassessment of the Civilian Radioactive Waste Management Program (DOE, 1989a), is that the focus of the near-term activities at the Yucca Mountain candidate site will be on surface-based testing. This testing is aimed specifically at evaluating whether any features or conditions exist at the site that would so adversely affect performance as to indicate that the site is not suitable for development as a repository.

One activity resulting from the Secretary's initiative, which continued through the reporting period, is the Surface-Based Testing Prioritization (SBTP) task. (The title SBTP will be changed to Testing Prioritization Task [TPT] as of October 1, 1990.) The objective of the SBTP is to review the current plans for conducting the testing program at Yucca Mountain and make recommendations to management on the prioritization of testing that would address the Potentially Adverse Conditions (PACs), specified in U.S. Nuclear Regulatory Commission (NRC) and DOE regulations, early during site characterization. In September, the scope of the SBTP task was expanded to consider all tests enumerated in the Site Characterization Plan (SCP). This change in scope was initiated to ensure an integrated approach to both surface-based and in situ testing programs relative to the emphasis on early detection of PACs.

Another initiative identified in the Secretary's report to Congress (DOE, 1989a) was the evaluation of alternatives to the top-level strategies in the SCP to determine if the schedule for licensing and developing a repository can be improved without compromising waste isolation or decreasing protection of public health and safety. A range of alternatives was considered, including options for evaluating site suitability and demonstrating regulatory compliance, alternative sets of licensing activities, alternative approaches to prioritization of testing, and options for repository and waste package

design. The draft report on this effort, known as the Alternative Licensing Application Strategy task (ATLAS), was completed on July 5, 1990, and an internal DOE review began in August. The final ATLAS report is anticipated in October 1990.

The DOE is also conducting a risk/benefit analysis of alternative strategies for characterizing the Calico Hills unit at Yucca Mountain. This unit is an important natural barrier between the proposed repository horizon and the underlying ground-water table. The need for this analysis is a consequence of a formal NRC objection to the SCP/Consultation Draft (SCP/CD) issued in January 1988. The NRC staff maintained that plans for excavation and testing in the unit, in conjunction with the planned exploratory shaft facility (ESF) excavations, were not based on an analysis of the risks and benefits of alternative methods for obtaining the needed information. The objection was resolved for the SCP issued in December 1988 on the condition that the analysis be performed and the NRC staff consulted before the results of the analysis are implemented. The scope of this activity has been expanded to include a multiattribute utility function of the Calico Hills unit, and the schedule for completion has been extended accordingly.

A formal evaluation of configuration and construction alternatives for the ESF continued during the reporting period. The study began by establishing a formal decision methodology to evaluate the relative attributes of various exploratory shaft and ramp configurations at the Yucca Mountain site. In parallel, 34 options for the ESF configuration have been developed that incorporate shafts and ramps at various locations. These options have been integrated with conceptual layouts for the proposed repository at Yucca Mountain and the two preferred configurations for excavations in the Calico Hills unit resulting from the first phase of the Calico Hills Risk/Benefit Analysis (CHRBA).

DOE has deferred further repository design until more information is available on the suitability of the site. Design of the ESF was also suspended pending completion of the ESF Alternatives Study.

Progress in the area of performance assessment included the Performance Assessment Calculational Exercises (PACE90). Areas investigated included scenario development, nominal scenario performance, performance under elevated fluxes, gas releases, and source-term sensitivity studies. DOE also participated in a technical exchange on performance assessment with the NRC in July 1990.

The DOE continued efforts to qualify the quality assurance (QA) programs of OCRWM, the Yucca Mountain Project Office (Project Office), and participating organizations. The DOE conducted 16 surveillances and 5 audits during the reporting period. Six participant QA programs were submitted to the NRC for acceptance. The OCRWM prepared upgraded plans and procedures to meet goals set for the Qualification Audit scheduled for October 1990.

A major product completed during the reporting period was the comprehensive report on the geophysical data available for the site, major results based upon them, and preliminary future plans for coordination and integration of the acquisition of new geophysical data. This report, Status

of Data, Major Results, and Plans for Geophysical Activities, Yucca Mountain Project (Oliver et al.), was published in July 1990.

DOE devoted significant effort to the development of study plans during the reporting period, especially those for ongoing activities, such as hydrologic, meteorologic, and seismic monitoring. These plans describe the activities to be conducted in greater detail than the SCP provides. They are the link between the studies described in the SCP and the technical procedures that will be used in the field and laboratory. There are 106 activities identified in the SCP for which study plans are needed. Over half of all the required study plans are in preparation or are completed.

Study plans are provided to the NRC for review and comment. By the end of the reporting period, 10 plans had been sent to the NRC and several more were expected to be transmitted in early fiscal year (FY) 1991. The NRC has completed review of the following study plans, without objection to the initiation of these studies: "Mineralogy, Petrology, and Chemistry of Transport Pathways," "Characterization of Volcanic Features," "Location and Recency of Faulting near Prospective Surface Facilities" and "Quaternary Regional Hydrology."

Significant progress has been made in several areas of the site characterization program, especially preparation for new site characterization activities which include Midway Valley exploratory trenching for assessing the proposed surface-facilities location and for trenching of calcite-silica deposits to help determine their origin. These activities are described in the NRC-accepted study plans listed above. Prototype dry-drilling operations to refine procedures for drilling exploratory boreholes at Yucca Mountain were also successfully completed.

Efforts to gain access to the Yucca Mountain site to conduct ground-disturbing site characterization activities were unsuccessful due to Nevada's refusal to issue necessary environmental permits. On December 26, 1989, the State of Nevada returned the DOE permit applications for the project. The State contended that, because the 1989 Nevada Legislature enacted Assembly Bill No. 222, Assembly Joint Resolution No. 4, and Assembly Joint Resolution No. 6, the storage of high-level radioactive waste in Nevada is prohibited. In addition, the Nevada Attorney General's Opinion (November 1, 1989) supported the prohibition of high-level radioactive waste storage in Nevada. The permit applications were returned with the statement, "These applications are now moot because the Yucca Mountain Repository is prohibited."

On January 5, 1990, the Nevada Attorney General filed a petition for review with the U.S. Court of Appeals for the Ninth Circuit, seeking a declaration by the Court that Nevada Assembly Bill 222 and Assembly Joint Resolutions 4 and 6 constituted a valid "notice of disapproval" of the Yucca Mountain site under Section 116 of the NWPA, as amended. In addition, the State sought an order prohibiting DOE from conducting any further studies at the site. Subsequent to this action by the State, DOE filed suit in the U.S. District Court in Nevada on January 25, 1990, requesting an order directing the State to act on the three environmental permit applications within 30 days and prohibiting the State from unlawfully interfering with DOE's efforts to comply with the NWPA, as amended. A decision in this case was stayed pending a disposition of the case filed in the U.S. Court of Appeals.

On September 19, 1990, the U.S. Court of Appeals for the Ninth Circuit issued its opinion, concluding that the Secretary's decision to conduct site characterization at Yucca Mountain is not contrary to law, and that he has no judicially enforceable duty to promulgate regulations governing the timing of site disqualification decisions. On December 17, 1990, the State of Nevada filed a petition for certiorari with the U.S. Supreme Court, seeking to have the Supreme Court review the determination of the Court of Appeals. Nevada has also requested the U.S. District Court in Nevada to continue its stay of the DOE's case, seeking issuance of the environmental permits, until the Supreme Court rules on the State's petition to the Supreme Court.

The Management Systems Improvement Strategy (MSIS) was developed by OCRWM during the reporting period to provide a new program approach for achieving the mission specified by the NWPA, as amended. The MSIS framework, devised to achieve functional integration in conjunction with the implementation of this strategy and the OCRWM reorganization, is expected to produce improvements to the technical baseline and other major OCRWM management documents.

The DOE participated in numerous interactions with regulatory agencies, oversight groups, affected governments, and the public during the reporting period. These included formal presentations, field trips and technical exchanges with the NRC and the Nuclear Waste Technical Review Board (NWTRB), with participation by the State of Nevada and local governments on major activities including the ESF Alternatives Study, the SBTP task, the CHRBA, and the ATLAS study. NRC, State, and county representatives also participated as observers at QA audits and surveillances of the Project Office and program participants. The DOE also held periodic public outreach meetings in Nevada.

1.0 INTRODUCTION

1.1 PURPOSE AND SCOPE OF THE PROGRESS REPORT

In accordance with the requirements of Section 113(b)(3) of the NWPA, as amended, the DOE has prepared this report on the progress of site characterization activities at Yucca Mountain in southern Nevada for the period April 1 through September 30, 1990. This report is the third of a series of reports that are issued at intervals of approximately six months during site characterization.

The DOE's plans for site characterization are described in the SCP for the Yucca Mountain site (DOE, 1988a). The SCP has been reviewed and commented on by the NRC, the State of Nevada, the affected units of local government, other interested parties, and the public. Responses to these comments have either been issued or are in preparation. More detailed information on plans for site characterization is being presented in study plans for the various site characterization studies and their component activities.

The progress report presents short summaries of the status of site characterization activities and cites the technical reports and research products that provide more detailed information on the activities. The report provides highlights of work started during the reporting period, work in progress, and work completed and documented during the reporting period. In addition, the report is the vehicle for the discussion of major changes, if any, to the DOE's site characterization program resulting from ongoing collection and evaluation of site information; the development of repository and waste-package designs; the receipt of performance-assessment results; and any changes that occur in response to external comments.

The progress report conveys information in a convenient summary form to be used for information purposes only. It is not the mechanism for controlling and documenting technical or policy positions regarding changes in schedules or the testing program. Such changes are controlled through DOE change-control procedures.

This third progress report is structured differently from previous progress reports. This is due, in part, to editorial preference by the Office of Geologic Disposal (OGD), the office responsible for the progress report since the recent reorganization of OCRWM. Also, the change in structure and level of detail is part of OGD's response to NRC comments on the first progress report. These NRC comments included suggestions for an activity-by-activity status. Accordingly, the progress report includes a detailed status of activities as defined by the structure of SCP Chapter 8, similar to the Technical Status Reports (TSRs) previously prepared by the Project Office.

The progress report consists of two main sections: (1) an introductory section, and (2) a section on the status of site characterization activities, which generally following the format of SCP Chapter 8. An appendix containing the current summary schedule for the repository program is included. A list of the documents cited in the text are available for inspection at DOE public

reading rooms in Washington, D.C. and the State of Nevada. A list of acronyms are also provided at the back of this report.

1.2 BACKGROUND INFORMATION

As stated in Section 160 of the NWPA, as amended, the Yucca Mountain site in Nevada has been selected as the candidate site for detailed study to determine if it is suitable for the United States' first geologic repository for spent nuclear fuel and high-level radioactive waste. The Yucca Mountain site has not been selected for a repository; rather, it has been designated as the only candidate site for study to assess its suitability for development as a repository.

The purpose of this detailed study is to obtain the information necessary to determine whether the Yucca Mountain site is suitable for a geologic repository and, if so, to provide the information necessary to prepare a license application for submittal to the NRC. If, during site characterization, the Yucca Mountain site is determined to be unsuitable for development as a geologic repository, the DOE will, in accordance with Section 113(c) (3) of the NWPA, as amended: (1) terminate all site characterization activities at such site, (2) notify the Congress, the Governor and legislature of Nevada of such termination and the reasons for such termination; (3) remove any high-level radioactive waste, spent nuclear fuel, or other radioactive materials at or in such site as promptly as practicable; (4) take reasonable and necessary steps to reclaim the site and to mitigate any significant adverse environmental impacts caused by site characterization activities at such site; (5) suspend all future benefits payments under subtitle F [42 U.S.C. 10173 et seq.] with respect to such site; and (6) report to Congress not later than 6 months after such determination the Secretary's recommendations for further action to assure the safe, permanent disposal of spent nuclear fuel and high-level radioactive waste, including the need for new legislative authority. After the completion of site characterization, and if the DOE believes that the Yucca Mountain site is suitable for development of a repository, a recommendation for approval of the site will be sent to the President. The recommendation will be accompanied by an Environmental Impact Statement. After recommendation by the DOE, if the President considers the site qualified, the President will recommend the site to the U.S. Congress, which only must act on the recommendation if the State of Nevada disapproves of the site recommendation at that time. If the Presidential recommendation becomes effective, the DOE will submit a license application to the NRC to obtain authorization to construct a repository at the site. Following construction, the DOE will apply for an amendment to the license to allow operation of the repository.

1.2.1 Site Characterization

The detailed study mentioned in the preceding section is referred to as site characterization. It is a comprehensive program of studies and component activities to collect information about the natural conditions of the site. These activities are integrated with activities to design a potential repository, a repository seals system, a waste package (i.e., the waste form

and the container in which it is packaged for disposal), and with the activities associated with performance assessments.

The information to be obtained through site characterization consists of data on the natural features of the site, such as those related to the geological, hydrological, geochemical, climatological, and meteorological conditions at the site. This information is obtained by conducting both surface-based and underground tests in the field as well as tests in the laboratory. The underground investigations will be conducted in an ESF. In the current conceptual design, the ESF consists of two exploratory shafts, excavated to the depth of the proposed repository horizon, providing access to underground testing rooms and tunnels. The ESF will also include various structures and buildings on the surface, such as a hoist house for the shafts and temporary buildings for laboratories and offices. As explained in detail elsewhere in this report, the configuration and construction methods for the ESF are currently undergoing extensive review.

No significant adverse environmental effects are expected to result from site characterization (DOE, 1986). However, the DOE, in consultation with the State of Nevada and affected units of local government, will conduct activities during site characterization to monitor environmental conditions and will implement appropriate mitigation measures that may be necessary. Plans for environmental monitoring and mitigation are described in the Environmental Monitoring and Mitigation Plan (EMMP) (DOE, 1988b). In addition, in response to Section 175 of the NWPA, as amended, the DOE submitted a report to the U.S. Congress identifying potential socioeconomic effects that may result from the repository program (DOE, 1988c). These potential effects will also be monitored. Results of monitoring activities will be reported semiannually in environmental and socioeconomic progress reports.

An EMMP Progress Report (EMMP/PR) was issued in September 1990. Since the issuance of the Section 175 Report, OCRWM has developed a Socioeconomic Plan (SP) for Yucca Mountain. The SP describes OCRWM's socioeconomic program for the site characterization phase and is designed to integrate data collection, data analyses, and reporting efforts. A consultation draft of the SP was issued in April 1990, and comments are expected from Nye and Clark counties. When all comments are received, follow-up efforts to resolve the comments will be initiated.

Chapter 2 of this report describes in detail the accomplishments of the site characterization program during the reporting period. Some of the major efforts discussed there include the following. Four major activities were either nearly completed or continued during the reporting period. These were the ESF Alternatives Study, the SBTP Task, the CHRBA, and the ATLAS study. The ESF Alternatives Study is examining various configurations (such as accessing the proposed repository horizon by ramps or shafts) and construction methods (such as tunnel boring machines) for the ESF. The SBTP Task is reviewing planned testing and will make recommendations on prioritizing these tests to focus on the early identification of potential disqualifying conditions at the site. The CHRBA is assessing the scope of testing needed to characterize the Calico Hills unit, a potentially important natural barrier underlying the proposed repository, and the risks to the waste isolation capabilities of the site associated with that testing. The ATLAS study evaluated the alternatives to the top-level strategies in the SCP to determine

if the schedule for licensing and developing a repository can be improved without compromising waste isolation or decreasing protection of health and safety.

Other major accomplishments included the successful completion of prototype drilling operations at Apache Leap, Arizona. These operations were conducted to determine the feasibility of drilling and coring boreholes dry in order to minimize disturbance of the in situ rock characteristics and also to refine procedures for conducting drilling at Yucca Mountain.

Preparation for new site characterization activities at Yucca Mountain was a high priority during the reporting period. Two activities, Midway Valley trenching and calcite-silica trenching, are expected to be initiated as soon as DOE gains access to the site. Consequently, efforts were focused on completing prerequisites to these activities, including development of applicable technical requirements, and completion of necessary design activities, environmental surveys, and QA requirements.

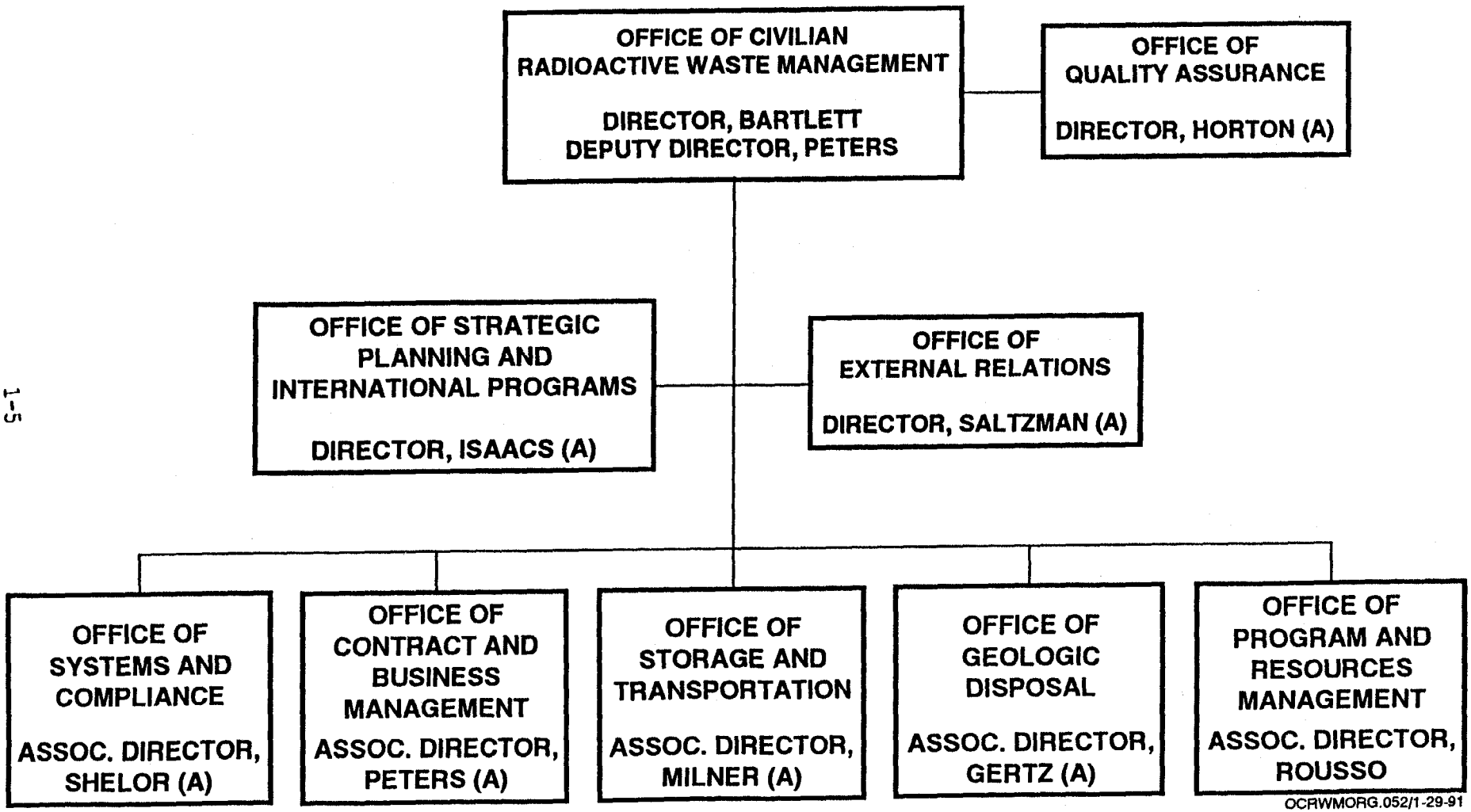
1.2.2 Programmatic Developments

In November 1989, the Secretary completed a comprehensive reassessment of the waste management program. One of the initiatives that resulted was concerned with management and organization. It included the appointment of a new OCRWM Director, establishment of direct-line reporting by the manager of the repository project to OCRWM at DOE/HQ, streamlining of contractor support, and implementation of more formal management controls. Following his appointment as OCRWM Director, Dr. John Bartlett initiated a reorganization designed to fulfill the Secretary's initiatives and develop a stronger goal-and-action oriented program.

The proposed OCRWM organization consists of five offices headed by associate directors and three offices headed by directors who report directly to the OCRWM Director. These offices are the Office of Geologic Disposal; Office of Storage and Transportation; Office of Systems and Compliance; Office of Contractor Business Management; and Office of Program and Resource Management, headed by Associate Directors; and the Office of External Relations; Office of Strategic Planning and International Programs; and Office of Quality Assurance, headed by Office Directors. This proposed organization is illustrated in Figure 1.0. The Office of Geologic Disposal is responsible for site characterization of Yucca Mountain.

Another effort related to efficient control of the repository program is the acquisition of a Management and Operations (M&O) contractor. Following challenges of the selection process, the DOE is negotiating details of the M&O contract with the team of contractors led by TRW, Inc. These negotiations are expected to result in issuance of the contract in FY 91.

The MSIS, a new management approach to be used for achieving the Congressional mandate for developing the waste management system, was issued during the reporting period. This strategy was designed to communicate the basic principles that underlie the management of the OCRWM program to interested parties and to all who are involved in applying this strategy to program operations.



(A) - Acting

Figure 1.1. (Proposed) Reorganization - Office of Civilian Radioactive Waste Management.

To move assertively in the implementation of this strategy, a number of initiatives have been identified, including a functional analysis of the physical system and programmatic functions. The results of these initiatives will be carefully phased into the mainstream of the program, using a formal change-control process, allowing for transition, and conserving resources by building onto the existing program. No component of the program will be removed until and unless a replacement is available. Existing processes will be used if they function satisfactorily. The MSIS is expected to produce not only near-term improvements in the progress of the program but also to provide the framework that will ensure the successful accomplishment of the program's mission.

Strategic planning is a systematic process of choosing an organization's basic directions. This process is being implemented in response to a Secretary of Energy Notice entitled "Strategic Planning Initiative" (SEN-25-90), issued July 24, 1990. It defines a department-wide and coordinated system of planning and budgeting. The first step, the annual strategic plan, was completed in September 1990. It discusses planning horizons with regard to waste emplacement in a licensed repository, presents a situation analysis of site characterization, addresses stakeholder and other needs, and establishes planning assumptions for the program. The next step, to be submitted to the Secretary in December 1990, is to develop "multiyear program plans," which are operational specifications of the goals and objectives developed in the strategic plan. This exercise is intended to drive the budget development process for FY 93, beginning in April 1991. In addition to providing money for site characterization, the process is intended to address issues such as how best to gain site access.

OCRWM is carrying out an international program in cooperation with several other nations. The program encompasses all aspects of the waste management system. Selected activities related to site characterization are described below.

OCRWM currently participates in several repository technology projects. These include the Stripa Project, sponsored by Europe's Organization for Economic Cooperation and Development. Phase III of this project, scheduled to be completed in 1991, has involved site characterization, the development of remote sensing instrumentation, and studies of radionuclide transport. The Pocos de Caldas Project in Brazil was completed in 1990. This project involved an analysis of migration patterns of naturally occurring uranium daughter products. Results of the analysis will be used to validate models of radionuclide transport. Also expected to be completed in 1990 is the INTRAVAL project that is directed at validating geosphere models for radionuclide transport. In addition to those from OCRWM, INTRAVAL has participants from 20 organizations from 11 nations.

The recent focus of the U.S. bilateral agreement with Switzerland has been on negotiating Project Agreement 3. It will likely focus on aspects of saturated and unsaturated flow, diffusive transport, and geophysical measurement techniques. The current focus of technical exchanges with Sweden concerns the study of geochemistry and saturated flow, nuclide transport, geology and tectonics, spent fuel characterization, container materials, mineral evolution, performance assessment, and assignment of a representative to the Project Office.

In July 1990, the Board on Radioactive Waste Management (BRWM) of the National Academy of Sciences (NAS) released its report on the OCRWM program entitled "Rethinking High-Level Radioactive Waste Disposal." The report addresses fundamental aspects of the program and makes recommendations for the DOE, the U.S. Congress, the U.S. Environmental Protection Agency (EPA), and the NRC. The Secretary has indicated that the DOE will respond to the report. This response is tentatively scheduled for completion in November 1990. The document will respond to the BRWM recommendations, including performance standards, licensing requirements, engineering design, modeling, design changes during construction, and peer review. On September 17-18, 1990, the BRWM conducted a symposium in Washington, D.C. to examine the status of licensing requirements in the U.S. and elsewhere. OCRWM personnel and many other interested parties attended this symposium which featured presentations from a wide array of groups.

In respect to another activity related to licensing requirements, the DOE provided comments on Working Draft 2 of 40 CFR 191, "Environmental Radiation Protection Standards for Management and Disposal of Spent Fuel, High-Level and Transuranic Radioactive Waste." The DOE activities relating to EPA standards are being coordinated by a Steering Group composed of representatives from Radioactive Waste (RW), Environmental Restoration and Waste Management (EM), Environment, Safety and Health (EH), and General Council (GC). At least one more working draft is expected before the proposed standards are issued for public comment.

While major efforts were expended during the reporting period in preparation for new site characterization activities, access to the site is still blocked by the State of Nevada's refusal to issue needed environmental permits. On December 26, 1989, the State of Nevada returned the DOE permit applications for the project. The State contended that, because the 1989 Nevada Legislature enacted Assembly Bill No. 222, Assembly Joint Resolution No. 4, and Assembly Joint Resolution No. 6, the storage of high-level radioactive waste in Nevada is prohibited. In addition, the Nevada Attorney General's Opinion (November 1, 1989) supported the prohibition of high-level radioactive waste storage in Nevada. The permit applications were returned with the statement, "These applications are now moot because the Yucca Mountain Repository is prohibited."

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2.0 STATUS OF SITE CHARACTERIZATION

2.1 PREPARATORY ACTIVITIES

2.1.1 Quality Assurance Program

During the reporting period, the DOE QA organization undertook the task of consolidating the OCRWM Headquarters QA Program documents with those of the Project Office. This exercise consisted of superseding the Project Office QA Program documents, incorporating the Project Office QA requirements into the OCRWM QA Program documents, and elevating the revision number of the OCRWM QA Program documents. The Yucca Mountain Project QA document titled "The Nevada Nuclear Waste Storage Investigations Project Quality Assurance Plan" was superseded by the OCRWM Quality Assurance Requirements Document (QARD), Revision 3, effective May 5, 1990. The Project Office Quality Assurance Program Plan 88-1, Revision 3 was superseded by the OCRWM Quality Assurance Program Description Document (QAPD), Revision 2, also effective May 5, 1990. Following this major consolidation effort, formal orientations to the new program documents were conducted for all DOE Project Office personnel as well as the Technical and Management Support Services (T&MSS) direct support personnel. The general QA indoctrination held for new employees was revised to include an overview of the QARD and the QAPD and how these documents are applied. The QARD and the QAPD were submitted to the NRC for their review and acceptance.

In support of the forthcoming DOE qualification audit, the Project Office QA Program Control staff continued reviews of existing quality implementing procedures to determine whether existing procedures need to be revised or consolidated to meet current requirements or whether new procedures need to be written. The activities performed by the Project Office QA Project Control staff in support of Midway Valley and Calcite Silica Studies have included the review of associated plans, requirements documents, grading packages, and procedures. Additionally, efforts were focused on participants to ensure that all open Project Office QA-generated deficiency documents have or will be addressed prior to their respective need date to support this task. On the schedule Readiness Reviews for Midway Valley and Calcite Silica studies activities are major upcoming line items involving Project Office QA. In addition to these activities, the Program Control staff is providing reviews in support of two (2) software QA plans that have yet to be approved. One additional software QA plan is in the development stage and is not ready for QA input.

The Project Office QA Verification staff continued to monitor the work of the Yucca Mountain Project participants, including the Project Office. During this reporting period, there were a total of 15 surveillances and 5 audits conducted on the participants. In addition, since some of the Verification staff will be a part of the audit team for the OCRWM QA qualification effort, a great deal of attention has been given in preparing checklists and establishing audit strategy.

In an effort to better understand the requirements, roles and responsibilities established by the QA program, a QA workshop was conducted during this reporting period. This workshop, held in Denver, Colorado, on

August 7, 1990, provided the forum for the scientific and engineering communities to better understand the QA program and allowed them the opportunity to provide input to QA program requirements and their implementation.

In the spirit of consultation and cooperation, the DOE and NRC conducted regularly scheduled meetings to discuss QA-related issues and the status of the QA program's qualification. DOE and NRC meetings were conducted in April, May, and July of 1990.

2.1.2 Exploratory Shaft Facility Design and Construction

Work on Title II design for the ESF was discontinued until the ESF Alternatives Study is completed. Several design packages representing subelements were not completed because of lack of design inputs. Design activities will continue when the recommended ESF option is identified by the ESF Alternatives Study.

The drawings in the first ESF design package showing the general arrangements of the surface facilities and features were put on hold at or near the design verification stage. This was done pending completion of the ESF Alternatives Study. The drawings contained in the second ESF design package, dealing with the headframe, collar and main test level (MTL), were modified to incorporate the comments submitted during the management review in September 1989. No further progress has been made pending completion of the ESF Alternative Studies.

The Architect/Engineers (A/E) continue to provide technical support for the ESF Alternatives Study.

The draft of the ESF Test Support Requirements Documents has been finalized and is under informal review by T&MSS.

The Integrated Data System continues to be on hold until transition to the new ESF A/E is complete.

2.1.2.1 ESF Alternatives Study

Work continued on the ESF Alternatives Study, as expert panels were formed and the task force proceeded to evaluate the 17 options previously identified. Preliminary results from the CHRBA task force were transmitted to Sandia National Laboratories (SNL) on June 30, 1990, for incorporation into the study. The transmittal identified two strategies for characterization of the Calico Hills unit (CHn), and the CHRBA task force recommended that the ESF be designed to accommodate exploration of the CHn to the extent envisioned in these strategies. Evaluation of the 17 options was curtailed in order for the recommendations from the CHRBA task force to be incorporated into the ESF layouts, data sheets, costs, and schedules used in the evaluation process. Furthermore, on August 8, 1990, in keeping with the importance accorded by the Director of OCRWM for an early evaluation of suitability of the Yucca Mountain Site, the ESF Alternatives Study task force was directed by the management panel to incorporate within the study a means of obtaining early access to the

CHn, and to consider this early access when selecting the preferred option for the ESF. Additionally, the site characterization testing strategy was reviewed and re-prioritized in order to identify those tests whose performance is essential during construction of the ESF accesses, (i.e. site suitability tests and those tests for which data would be irretrievable if not acquired during construction). Accordingly, 17 additional options were developed to allow early access to the CHn and to accommodate the new test strategy, and revised layouts, data sheets, costs and schedules were developed. The evaluation process, now considering a total of 34 options, continued in late September 1990. A major meeting with the NWTRB occurred on April 7, 1990, with the topics presented being proposed decision methodology, major options identified, and current status of the study. A second meeting with the NWTRB was held on July 25, 1990, at which the options and supporting information, methodology development, pilot study results, methodology implementation, and current status were presented. The study task force will continue to evaluate the identified options, and to establish scores and weighting factors which can be used in the decision methodology to rank each option. The ranking of options will allow important features of each option to be evaluated, and this information will be used to establish a preferred option for recommendation to the DOE.

2.1.3 Surface-Based and Underground Testing Program

2.1.3.1 Surface-Based Testing Prioritization (SBTP) Task

The SBTP is a DOE initiative identified in the Secretary of Energy's "60-day report" to Congress (DOE, 1989a). The objective of the SBTP is to review the current plans for conducting the testing program at Yucca Mountain and make recommendations to management on the prioritization of testing that would address the PACs early during site characterization. The basis for this evaluation is to determine if the PACs of 10 CFR Part 60, 10 CFR Part 960, and other site conditions that could jeopardize performance, are adequately addressed by the current program priorities and schedules. Many of the comments and issues raised by the NRC, NWTRB, Edison Electric Institute (EEI), Advisory Committee on Nuclear Waste (ACNW), State of Nevada, etc., are also being considered.

The SBTP is implemented by a task force composed of two teams: a core team responsible for conducting the evaluation, and an integration team that serves as a resource group to provide expertise in various site characterization or performance assessment areas as required by the core team. In September 1990, an integration team was designated to conduct the approach discussed below.

A two-phase approach was adopted for the SBTP. Phase One will develop a spreadsheet model that considers the PACs and the disqualifying conditions in 10 CFR Part 960, and will yield recommendations for test prioritizations that can be utilized in December 1990. Phase Two in the decision analysis methodology will include a total system performance assessment model in conjunction with a decision tree analysis which calculates the consequences of expected and possibly adverse conditions. Phase Two will yield test prioritization results that can be utilized in the latter part of 1991. The core team completed a demonstration of the Phase One methodology in September.

The structured decision analysis methodology used for Phase One utilizes decision-aiding methodologies to construct decision and uncertainty trees to identify concerns and potentially adverse conditions for post-closure behavior of a proposed repository at Yucca Mountain. Next, these PACs and concerns are ranked according to their importance to waste isolation, and tests are identified that can investigate the presence of the most important adverse conditions. Finally, categories of these tests are evaluated and ranked according to their accuracy in detecting the condition. The tests can also be ranked according to other factors related to benefits and costs of testing.

In September, the scope of the SBTP task was expanded to consider all tests enumerated in the SCP. (The title SBTP will be changed to Testing Prioritization Task [TPT] as of October 1, 1990.) Additionally, the development of a Suitability Methodology was made separate from the TPT. Consistency between the SBTP and the Suitability Methodology Task is being maintained.

2.1.3.2 Alternatives to License Application Strategy (ATLAS) Task

A draft report for the ATLAS Task was completed on July 5 and an internal DOE review of the document began in August. The draft report contains a description of the decision-aiding methodology used to analyze licensing alternatives developed during an elicitation process. Approximately 80 specific licensing scenarios were analyzed, combined, and augmented during several ATLAS core group working sessions held during March and April. Alternative licensing strategies are expected to be developed for major stages of the characterization program. These strategies will form the basis for recommendations to the OCRWM, with each recommendation identifying specific actions that could be taken. Review of the document and incorporation of comments took place in September, and delivery of a final ATLAS Report to OCRWM is anticipated for mid-October.

2.1.3.3 Risk/Benefit Analysis of Alternative Strategies for Characterizing the Calico Hills Unit at Yucca Mountain

The need for a risk/benefit analysis of alternative strategies for characterizing the CHn hydrologic unit at Yucca Mountain resulted from an NRC objection to the SCP/CD. This objection maintained that the SCP/CD plans for excavation and testing in the CHn unit, in conjunction with the planned ESF excavations, were not based on an analysis of the risks and benefits of alternative methods for obtaining the information. The objection was lifted on the conditions that the analysis will be performed and that the NRC staff will be consulted before the results of the analysis are implemented.

Much of the effort in this study has been directed toward understanding the contribution of the CHn unit to total systems performance and the impacts of characterization on total systems performance. Three basic questions were evaluated: (1) is direct excavation in the CHn unit required to obtain data for licensing; (2) can the excavation be performed outside the repository block; and (3) if excavation is required within the repository block, can it be done from the ESF while limiting adverse impacts to the extent practicable? A preliminary decision model was developed to evaluate costs associated with

using erroneous information on total system performance as the basis for future repository licensing, construction, and operation decisions. The model suggests that if site performance is as good as existing data suggest, then the DOE can proceed with license application with negligible risk of failure. No testing program will affect this result; therefore, the model says testing has little or no value.

The no-testing result is being reconsidered because it only considers total systems performance and does not encompass the need to develop "scientific and regulatory" consensus, to consider subsystem performance objectives, and to evaluate alternative conceptual models. Consequently, in June the Calico Hills working group recommended that the ESF working group plan for extensive characterization of the repository block, supported by the ESF. This recommendation was made because the potential gain from extensive characterization is significant, and the impacts on total system performance are minor. The recommendation also noted that extensive characterization may not be needed, but the capability should be there. These results, along with alternative testing strategies, were presented to the NWTRB on July 24 and 25, 1990.

A workshop was held on September 5, 1990, to identify additional considerations not addressed in the value of information analysis, which might explain why it assigns a low value to the CHn unit testing strategies and which could, if addressed, lead to a conclusion that one or more testing strategies should be pursued, at least in a phased approach. Three considerations were identified in this workshop: (1) the development of scientific consensus; (2) evaluation of the value of a test when the test could discover unanticipated features; and (3) the possible phasing of tests, committing limited resources and preserving the option of conducting tests at a later date. The DOE is currently expanding the working group activities to include a multiattribute utility function of CHn performance rather than focusing only on total systems performance. This may address some of the "undercounting" in the value of testing results from the initial analysis, which focused on total systems performance. The schedule for completion of the CHRBA will be extended to account for this additional analysis.

2.1.4 Permits

2.1.4.1 Compliance with Federal Environmental Requirements

During the reporting period, environmental regulatory compliance activities continued in an effort to obtain environmental regulatory approvals for site characterization activities at Yucca Mountain.

On July 17, 1990, the U.S. Army Corps of Engineers (COE) issued the Yucca Mountain Project (Project) a permit for site characterization activities under the COE nationwide permit program. This program applies to those projects with less than one acre of disturbance to a waterway as defined by Section 404 of the Clean Water Act. The COE had been waiting to authorize work until consultations are completed with the U.S. Fish and Wildlife Service (USFWS).

The application for a Free Use Permit for use of sand, gravel, and fill material on land administered by the U.S. Bureau of Land Management (BLM)

during site characterization, as required by the Materials Act, will be issued in October 1990. The BLM was delaying approval until completion of consultations with the USFWS concerning the desert tortoise.

During the last reporting period, the USFWS issued their Biological Opinion finding that the Project would not jeopardize the desert tortoise population. Consultations continued with the USFWS to satisfy the Biological Opinion stipulations. A worker training program was developed to instruct workers on how to protect the tortoise and was sent to USFWS for review.

Discussions continued with the National Park Service (NPS) to address their concern that Project water use during site characterization may affect ground-water resources in Devil's Hole, which is part of the Death Valley National Monument, and in Ash Meadows. The NPS is protesting all new applications in the region, but has stated that establishing a monitoring program would satisfy its concerns. Consequently, a water-monitoring program was developed in consultation with the NPS to satisfy this suggested permit condition. The monitoring program is expected to be approved by NPS during the next reporting period.

On September 12, 1990, the first EMMP/PR was released. The report describes the accomplishments of the program established by the EMMP during the period September 15, 1988 through August 31, 1990. The report was made available to the NRC, the Governor of Nevada, the Nevada Legislature's Committee on High-Level Radioactive Waste, the NWTRB, affected units of local government, and the interested public. The DOE developed the EMMP to ensure that any unexpected adverse environmental impacts, should they occur, are detected and minimized before they become significant. The EMMP/PR documents compliance with Sections 113(a) of the Nuclear Waste Policy Act.

2.1.4.2 Compliance with State Environmental Requirements

On December 26, 1989, the State of Nevada returned the DOE permit applications for the project. The State contended that, because the 1989 Nevada Legislature enacted Assembly Bill No. 222, Assembly Joint Resolution No. 4, and Assembly Joint Resolution No. 6, the storage of high-level radioactive waste in Nevada is prohibited. In addition, the Nevada Attorney General's Opinion (November 1, 1989) supported the prohibition of high-level radioactive waste storage in Nevada. The permit applications were returned with the statement, "These applications are now moot because the Yucca Mountain Repository is prohibited."

On January 5, 1990, the Nevada Attorney General filed a petition for review with the U.S. Court of Appeals for the Ninth Circuit, seeking a declaration by the Court that Nevada Assembly Bill 222 and Assembly Joint Resolutions 4 and 6 constituted a valid "notice of disapproval" of the Yucca Mountain site under Section 116 of the NWPA, as amended. In addition, the State sought an order prohibiting DOE from conducting any further studies at the site. Subsequent to this action by the State, DOE filed suit in the U.S. District Court in Nevada on January 25, 1990, requesting an order directing the State to act on the three environmental permit applications within 30 days and prohibiting the State from unlawfully interfering with DOE's efforts to

comply with the NWPA, as amended. A decision in this case was stayed pending a disposition of the case filed in the U.S. Court of Appeals.

On September 19, 1990, the U.S. Court of Appeals for the Ninth Circuit issued its opinion, concluding that the Secretary's decision to conduct site characterization at Yucca Mountain is not contrary to law, and that he has no judicially enforceable duty to promulgate regulations governing the timing of site disqualification decisions. On December 17, 1990, the State of Nevada filed a petition for certiorari with the U.S. Supreme Court, seeking to have the Supreme Court review the determination of the Court of Appeals. Nevada has also requested the U.S. District Court in Nevada to continue its stay of the DOE's case, seeking issuance of the environmental permits, until the Supreme Court rules on the State's petition to the Supreme Court.

2.1.5 Land Acquisition

2.1.5.1 Land Withdrawal

To preclude the compromise of site characterization studies by the action of mining claimants, a land withdrawal application for approximately 4,255.5 acres of public land on Yucca Mountain was filed with the BLM by the Project Office in early 1989. The application requested that the land be withdrawn from the operation of the mining and mineral leasing laws only. Management of all other resources would remain with the BLM.

Activities supporting the application consisted of preparing a Land Withdrawal Report and Mineral Evaluation. These documents, along with a Biological Assessment concerning the desert tortoise, a Programmatic Agreement with the Advisory Council on Historic Preservation, and a U.S. Fish and Wildlife Service letter concerning threatened and endangered species, were transmitted to the Nevada State Office of the BLM on January 17, 1990.

The State Office of the BLM, using these inputs, prepared a case file for transmittal to BLM Headquarters for further review and refinement. At the conclusion of this step, the case file was presented to the U.S. Department of the Interior (DOI) for action.

The withdrawal was completed with issuance of Public Land Order (PLO) 6802, and became effective on September 25, 1990. Notice of the PLO was published in the Federal Register on September 25, 1990. This land will be withdrawn from mining and mineral leasing laws for a period of 12 years.

2.1.5.2 Participant Requests to Initiate Site Activity

Nine participant requests to initiate site characterization activity were processed during this reporting period. A participant request to initiate site activity is a prerequisite that requires acquisition of the land required to accomplish the activity. Significant requests included the 55-location regional seismic station network and gauging stations for the regional surface-water network.

2.1.6 Public Outreach

Response packages for comments made at the SCP Public Hearings in March 1989 were released August 1; these include Amargosa Valley Public Hearing comments (DOE, 1990b), Reno Public Hearing comments (DOE, 1990c), and Las Vegas Public Hearing comments (DOE, 1990d). Responses to written comments submitted at the hearings were also released as part of these packages. Copies of the response documents were sent to commentors, other public agencies and interested parties, and are also available in DOE reading rooms. Numerous individuals who commented on the SCP by letter during the public comment period (January 15-June 1) have had responses returned to them. DOE is responding to comments received on the Statutory SCP in 1989, and will continue to respond to all comments on the characterization program as they are received.

Previously released response packages, which addressed comments made on the SCP/CD packages, responded to comments from the following organizations: EEI (DOE, 1989b), U.S. Geological Survey (USGS) (DOE, 1989c), NRC (DOE, 1988d), and the State of Nevada (DOE, 1989d).

Transcripts of the public information meetings held in Tonopah, Fallon, and North Las Vegas during April 1990 were reviewed by Project Office technical staff to determine if concerns expressed were currently addressed in the planned site characterization program. The staff found that all concerns expressed at the meetings were being addressed by DOE's planned program.

Responses to comments on the statutory SCP received from the following agencies are in the final stages of review: California Energy Commission (38 comments); Lincoln County Board of Commissioners (6 comments); U.S. Environmental Protection Agency (EPA) (12 comments); EEI (28 comments); DOI (35 comments); NRC (2 objections, 133 comments, 63 questions); and State of Nevada comments on the ESF (58 comments).

The State of Nevada's main comment package on the SCP (September 1989) has had individual comments identified (1,917 comments), which have been categorized and assigned to working groups for preparation of draft responses. Comments in this package that are related to near-term characterization activities have been identified and will be responded to before initiating new site characterization work.

2.1.7 Interactions with NRC and Oversight Organizations

During the reporting period, the Project Office committed a significant level of effort in support of briefings, technical exchanges, meetings, and site visits with the NRC and Project oversight groups. The Project Office participated in four meetings and three site visits with the NWTRB. The NWTRB was created by the NWPA, as amended, and its members are appointed by the President to advise Congress and the Executive Office on the conduct and progress of the DOE high-level waste program. The full board contains several panels composed of experts that interface with various aspects of the DOE program. The four meetings held were: (1) a Structural Geology and Geoengineering panel briefing on April 12; (2) an Environmental and Public Health panel briefing on April 24-26, which included a field trip; (3) a

meeting on ESF alternatives, SBTP, and the CHRBA on July 24-25; and (4) an Engineered Barrier System (EBS) panel briefing on August 28-29. In addition to the technical briefings, three site visits were made to (1) Apache Leap, Arizona, to observe prototype drilling; (2) SNL to observe the ESF alternatives scoring process; and (3) G- and N-Tunnels at the Nevada Test Site (NTS).

The Project Office also participated in several interactions with the NRC, some of which involved visits to the Yucca Mountain site and to participant laboratories. Technical exchanges conducted over the reporting period included (1) an exchange on seismic hazards, which included a field trip; (2) an exchange on ESF alternatives; (3) a meeting and site visit to SNL to discuss performance assessment; (4) an exchange on radionuclide adsorption; and (5) an exchange on unsaturated zone (UZ) hydrology and geochemistry. One formal meeting was held in July to schedule future interactions, and four QA meetings and one QA workshop were held.

In addition, the Project Office has supported several interactions with the ACNW, an advisory body to the NRC, and with the Center for Nuclear Waste Regulatory Analysis (CNWRA). The CNWRA is a dedicated, federally-funded research and development center for the NRC. The CNWRA will perform analysis and research to reduce regulatory uncertainties prior to the licensing process for a geologic repository for high-level waste.

2.1.8 Comments on the Technical Program

Comments on Study Plan 8.3.1.5.2.1, "Characterization of the Quaternary Regional Hydrology" and 8.3.1.17.4.2, "Location and Recency of Faulting Near Prospective Surface Facilities," have been received from the NRC. Responses are currently under development. Comments applicable to these two study plans have been identified in the main State of Nevada comment package, and response packages for these comments are being prepared on an accelerated schedule.

In August, the NRC completed the acceptance/start work review of Study Plans 8.3.1.3.2.1, "Mineralogy, Petrology, and Chemistry of Transport Pathways," and 8.3.1.8.5.1, "Characterization of Volcanic Features." The purpose of a start work review is to identify concerns with studies, tests, or analyses that, if started, could cause significant and irreparable adverse effects on the site, the Site Characterization program, or the eventual usability of the data in licensing. The NRC had no objection to starting work for either plan. It is the intention of the NRC to offer detailed technical comments on both of these study plans in the future.

On July 31, 1989, the NRC provided comments on DOE's SCP. This Site Characterization Analysis (SCA) contained 2 objections, 133 comments, and 63 questions. The SCA was published by the NRC as NUREG-1347 (NRC, 1989). DOE responses to the NRC comments are in the final stages of review and concurrence. The following tables show the status of unresolved NRC comments on the SCP/CD and provide possible means of resolution. These comments were not resolved through revision to the statutory SCP.

Table 2.1 shows the status and proposed method of resolution of the NRC's open items originating from the SCP/CD Point Papers and the SCA. Table 2.2

TABLES 2.1 AND 2.2 STATUS AND POSSIBLE MEANS OF RESOLUTION OF NRC OPEN ITEMS ORIGINATING FROM SCP/CD POINT PAPERS AND THE SCA

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*KEY TO POSSIBLE/PROPOSED METHOD OF RESOLUTION:

1. Acquisition of new site data is needed for resolution.
2. Concern addressed through ESF Alternatives Study.
3. Concern addressed through CHRBA.
4. Concern addressed through either (1) SBTP study (including subsequent expansion of effort to TPT to include underground/in situ testing), or (2) development and implementation of site suitability methodology.
5. Concern addressed by implementation of study plan/activity or other design studies in current technical baseline.
6. Regulatory interactions (i.e., technical exchange, formal meeting, and/or rulemaking).
7. Implementation of approved DOE and participant QA programs.
8. Design control plans and procedures, readiness review.

TABLE 2.1 STATUS AND POSSIBLE MEANS OF RESOLUTION OF NRC OPEN ITEMS ORIGINATING FROM SCP/CD POINT PAPERS AND THE SCA

CDSCP POINT PAPER		SCA OBJECTIONS, COMMENTS, QUESTIONS INCORPORATING UNRESOLVED SCP/CD COMMENTS	RESOLUTION STATUS*
OBJECTION	1	Comment 6	Open; 1, 4
	3	Objection 1	Open; 2
	5	Objection 2	Progress tracked according to DOE/NRC agreement on QA program implementation
COMMENT	1	Comment 4	Open; 1, 4, 5
	3	Comment 5	Open; 6
	4	Comment 3	Open; 4
		Comment 9	Open; 4
		Comment 7	Open; 4
	13	Comment 19	Open; 1, 4
	17	Comment 24	Open; 5
	18	Comment 25	Open; 4, 5
	20	Comment 25	Open; 4, 5
	22	Comment 31	Open; 5
	26	Comment 32	Open; Geophysics "White Paper" was published in July 1990. See Oliver et al., 1990.
	28	Comment 35	Open; 4
	30	Comment 41	Open; 2, 4, 5
	35	Comment 42	Open; 5
	36	Comment 49	Open; 5
	37	Comment 8	Open; 4
		Comment 48	Open; 1, 5
	38	Comment 53	Open; 5
	39	Comment 53	Open; 5
	43	Comment 4	Open; 1, 4, 5
	44	Comment 4	Open; 1, 4, 5
	45	Comment 55	Open; 1, 4, 5
	49	Comment 51	Open; Geophysics "White Paper" was published in July 1990. See Oliver et al., 1990.
	50	Comment 60	Open; 1
		Comment 61	Open; 1
		Comment 62	Open; 1
		Comment 63	Open; 1
	51	Comment 52	Open; 1, 5; Geophysics "White Paper" was published July 1990. See Oliver et al., 1990.
	52	Comment 66	Open; 5

TABLE 2.1 STATUS AND POSSIBLE MEANS OF RESOLUTION OF NRC OPEN ITEMS ORIGINATING FROM SCP/CD POINT PAPERS AND THE SCA (continued)

CDSCP POINT PAPER		SCA OBJECTIONS, COMMENTS, QUESTIONS INCORPORATING UNRESOLVED SCP/CD COMMENTS	RESOLUTION STATUS*
	62	Comment 71	Open; 1, 2, 3, 4, 5
	64	Comment 74	Open; 5, 6
	65	Comment 72	Open; 2, 6
	66	Question 24	Open; 1, 2, 5, 6
	70	Comment 73	Open; 1, 2, 6
	72	Comment 77	Open; 1
	73	Comment 84	Open; 6
	77	Comment 85	Open; 1
	80	Comment 86	Open; 1
	82	Comment 87	Open; 1
	90	Comment 110	Open; 6
	91	Comment 98	Open; 1, 4
	92	Comment 108	Open; 4
	93	Comment 107	Open; 4
	94	Comment 95	Open; 1, 4
	95	Comment 49	Open; 5
	100	Comment 35	Open; 1, 2, 3, 4, 5
	103	Comment 119	Open; 2, 5, 6
	106	Comment 126	Open; 7
	108	Comment 125	Open; 1
	109	Comment 80	Open; 6
QUESTION	2	Comment 7	Open; 4
	13	Comment 34	Open; 4, Geophysics "White Paper" was published in July 1990. See Oliver et al., 1990.
	20	Question 13	Open; 5
	25	Question 16	Open; 5
	32	Comment 67	Open; 5
	33	Comment 32	Open; Geophysics "White Paper" was published in July 1990. See Oliver et al., 1990.
	37	Question 21	Open; 5
	41	Question 26	Open; 5
	43	Question 44	Open; 5
	44	Question 45	Open; 8
	46	Comment 95	Open; 1, 4
	47	Question 3	Open
	49	Question 3	Open
	51	Question 17	Open; 5
	52	Comment 1	Open; 1

TABLE 2.2 STATUS OF ESF OPEN ITEMS AND POSSIBLE MEANS OF RESOLUTION

ESF OPEN ITEM	CDSCP POINT PAPER	SCA COMMENT	RESOLUTION STATUS*
1		---	2, 4, 5, 6
2		---	6, 7
3		---	2, 3, 6
4		---	2, 6, 8
5		---	7, 8
6	Objection 3 Comment 98	Objection 1 RESOLVED	2, 6
8		---	2, 4, 5, 6
9	Comment 100	Comment 35	1, 2, 5
18		---	5, 6
19		---	5, 6
20	Comment 64 Question 42	Comment 74 RESOLVED	5, 6
21		---	2, 5, 6
22		---	6
23		---	6
24	Comment 66	Question 24	1, 2, 5, 6
26	Comment 65	Comment 72	2, 6
28	Comment 70	Comment 73	1, 6
31		---	2, 6
32		---	2, 6
35		---	6
40	Comment 43	Comment 4	1, 4, 5
41	Comment 44	Comment 4	1, 4, 5
42	Comment 45	Comment 55	1, 4, 5
46	Comment 1	Comment 4	1, 4, 5
47	Comment 30	Comment 41	2, 4, 5
48	Comment 103	Comment 119	2, 5
51	---	---	8
52	---	---	2, 8
53	---	---	5, 7, 8
54	---	---	5, 7, 8
55	---	---	5, 8
56	---	---	2

shows the status of ESF open items and their relationship to SCP/CD Point Papers and SCA comments.

2.2 SITE PROGRAMS

The site characterization effort for the Yucca Mountain site consists of a number of component programs. These programs are as follows:

- Geohydrology - includes investigation of surface and subsurface hydrology on both site and regional scales, with ground-water flow system characterization and modeling for both the unsaturated and saturated zones (SCP Section 8.3.1.2).

- Geochemistry - includes investigation and modeling of rock chemistry and mineralogy, ground-water chemistry, and geochemical behavior of materials along potential radionuclide transportation pathways (SCP Section 8.3.1.3).

- Rock Characteristics - includes characterization and modeling of rock stratigraphic and structural features and distributions within the site area, and integration of geophysical and drilling activities to obtain subsurface stratigraphic and structural data (SCP Section 8.3.1.4).

- Climate - includes analysis of paleoclimate, paleohydrology and paleoenvironment, and characterization of modern climate, future climate, and future hydrology (SCP Section 8.3.1.5).

- Erosion - characterizes modern and past erosion and evaluates the potential effects of future climate and tectonics on erosion (SCP Section 8.3.1.6).

- Postclosure Tectonics - characterizes tectonic features such as igneous activity and fault and fold deformation in the Yucca Mountain vicinity, with emphasis on volcanic activity, and analyzes the potential effects of tectonic processes on a potential repository and the site ground-water system (SCP Section 8.3.1.8).

- Human Interference - evaluates the known and potential natural resources in the site area, and the potential for future human intrusion into the site area in search of such resources (SCP Section 8.3.1.9).

- Meteorology - characterizes the site and regional meteorological conditions of the Yucca Mountain vicinity (SCP Section 8.3.1.12).

- Offsite Installations and Operations - determines the presence of offsite industrial, transportation and military installations and operations in the Yucca Mountain vicinity, and what potential impacts these installations and operations might have on the site area (SCP Section 8.3.1.13).

- Surface Characteristics - characterizes the properties of surficial soil and rock materials and topographic characteristics in the site area (SCP Section 8.3.1.14).

- Thermal and Mechanical Rock Properties - determines rock thermal and mechanical properties from laboratory and in situ investigations, and characterizes thermal and mechanical stress conditions at the site (SCP Section 8.3.1.15).

- Preclosure Hydrology - characterizes the potential for flooding, and determines location of an adequate water supply for repository construction and operation and preclosure hydrologic conditions in the unsaturated zone at Yucca Mountain (SCP Section 8.3.1.16).

- Preclosure Tectonics - characterizes faults, seismicity and tectonic stress field, and evaluates the potential for faulting, ground motion and volcanic ash fall in the site vicinity (SCP Section 8.3.1.17).

These programs are discussed in detail in Sections 2.2.1 through 2.2.13.

2.2.1 Geohydrology (SCP Section 8.3.1.2)

2.2.1.1 Study 8.3.1.2.1.1 - Characterization of the Meteorology for Regional Hydrology

Review comments on Study Plan 8.3.1.2.1.1 were received by the USGS from the Project Office and DOE/HQ. Revisions to the study plan and comment resolution are in progress.

Activity 8.3.1.2.1.1.1 - Precipitation and Meteorological Monitoring. The Hydrologic Research Facility (HRF) was linked with the Weather Service Nuclear Support Office's (WSNSO) Micro Integrated Storm Information System (MISIS). Using inexpensive software and existing computer resources, this system provides an economic way of obtaining near real-time lightning data. The link is via dedicated telephone circuit operating at 9600 baud. Strikes are color-coded to indicate the age of lightning strikes up to two hours old. These data are valuable in tracking thunderstorms in the vicinity of Yucca Mountain to locate the area of maximum rainfall. However, this system is only a temporary, partial solution of the requirement for storm tracking. The MISIS is limited because the data cannot be archived or replayed. This capability is necessary for future reanalyses and study of significant precipitation events affecting Yucca Mountain and the Upper Amargosa River Watershed. To meet this reanalysis requirement, a capital purchase of more sophisticated computer hardware and software was submitted.

A capital purchase was made for hardware, software, and communication equipment necessary to establish a weather satellite ground station. Once in place, the HRF will be able to receive and archive data from both the Geostationary Environmental Operational Satellite and polar-orbiting weather satellites. Satellite data will be used in conjunction with surface-based precipitation data and lightning data to study individual storm events affecting Yucca Mountain and the Upper Amargosa River Watershed.

The HRF acquired historical precipitation data from 1957 to present from the WSNSO's climatological NTS rain gage site (called 4JA) in Jackass Flats near the HRF. A portion of the data, which includes significant rainfall occurrences (August-December 1984), was sent to Oregon State University for correlation with heavy runoff events in Pagany Wash during this period.

An analysis of historical precipitation data, from NTS rain gage 4JA and from Nevada locations at Beatty, Las Vegas, and Caliente, was begun to study the duration, intensity, and frequency of rainstorms. This study includes data covering a 23-year period and will help to determine the distribution and frequency of rainfall events within Southern Nevada. The study will also provide an estimate of historical rainfall patterns at Yucca Mountain and the Upper Amargosa River Watershed.

Calibration of tipping rain gages continued, and one additional gage was installed in Pagany Wash. Installation of an additional 20 or more rain gages at selected locations is also planned in the Upper Amargosa River Watershed and at Yucca Mountain.

Research is continuing to determine the best way to obtain centrally-produced National Weather Service charts. These daily charts are essential in reviewing precipitation events and preparing case studies. The WSNSO weather station at Mercury, Nevada, agreed to save maps in their computer network for up to five days and to print copies as needed when significant storms affect Yucca Mountain. Weather plotting charts were obtained of varying size and description. These charts will be used to document studies of significant rainfall events at Yucca Mountain and vicinity.

Methods to create time-lapse photographs of cloud development were investigated. Possibilities range from use of videotape techniques to motion picture film. Research is continuing to determine the most cost-effective means of recording and archiving cloud development over Yucca Mountain.

The WSNSO has established a bulletin board called the Meteorological Alert Distribution System (MADS). The HRF can now dial into this system to obtain the latest weather information from the NTS Meteorological Data Acquisition Network, surface and upper air observations from Desert Rock (Mercury, Nevada), forecasts for the NTS, as well as other weather information. This source of data will be valuable to the Project in terms of corroborative information. It will be used to help identify weather systems affecting the Yucca Mountain region.

Research continued to determine procedures for obtaining weather data from the BLM and the Desert Research Institute (DRI), who both operate automated weather stations in southern Nevada, continued. These corroborative data will be needed on at least a monthly basis to help characterize the regional meteorology of the Yucca Mountain area.

Total annual precipitation data for 1988 from reporting stations in southern Nevada and southeastern California were analyzed. The purpose of this analysis is to determine precipitation patterns in relation to Yucca Mountain and to assess the extent of the drought in the southwestern U.S. The analysis takes terrain elevation into account and provides an estimate of

total annual rainfall amounts where the actual data are missing. A similar analysis will be done for 1989 data, with yearly analyses planned for the future.

Meetings were held at the National Center for Atmospheric Research (NCAR) in Boulder, Colorado, on August 7, 1990, to coordinate climatic and hydrologic modeling. The NCAR has completed development on a mesoscale model, MM4, which is a higher resolution subset of the Global Climate Model (GCM) and is centered on Yucca Mountain. The NCAR is currently running historical data from 1982 to 1985 on the MM4 in order to calibrate the model. Subsequent runs will then be made to estimate the future climate. The NCAR plans on completing the historical data run by October 1990. At the August conference, a presentation was made to provide insight into the characterization of meteorology and infiltration at Yucca Mountain that is needed by the climate model. Measurements of precipitation and evapotranspiration have been identified by the NCAR as site-specific needs for model calibration, which will be provided by the meteorology and infiltration programs.

The HRF provided the paleoclimate research group with the mean annual temperature for Corn Springs, Nevada. This temperature datum was based on historical data recorded at the Desert National Wildlife Refuge. It was corroborated by interpolation between data from Nellis Air Force Base and Desert Rock by plotting on a Skew-T Log-p atmospheric diagram. The mean annual temperature was determined to be 17°C.

Ongoing monitoring work included operation of nine automated tipping-bucket precipitation gages and a prototype network of 87 plastic rain storage gages at Yucca Mountain. Seven precipitation events were documented during the reporting period. Geostatistical analyses were completed on each of these events to determine storm character and to search for a relationship between rainfall amounts and elevation.

2.2.1.2 Study 8.3.1.2.1.2 - Characterization of Runoff and Streamflow

Study Plan 8.3.1.2.1.2 was approved by the Project Office and submitted to DOE/HQ for transmittal to the NRC.

Activity 8.3.1.2.1.2.1 - Surface-Water Runoff Monitoring. Operation of five continuously recording stream gages, ten peak-flow sites, and 21 precipitation gages continued. Equipment and materials ordered for six new stream gages were received. Installation of the gages was delayed pending environmental and access authorizations from DOE. A capital equipment request for an "ALERT" telemetry network for the recording sites was submitted to Reynolds Electrical and Engineering Company (REECo) for procurement. The "ALERT" telemetry base station, located in Las Vegas, was made fully operational. Testing of the system will commence when the telemetry lines to the NTS are established by REECo Communications. A criteria letter requesting NTS contractor support for performing streamflow simulation at a gage site in Upper Fortymile Wash was approved and forwarded to the Project Office for action. Of particular significance was the series of runoff events that occurred in many areas of southern Nevada during the months of June, July, and August. Evaluation of these flows was made through indirect evidence of runoff in the Amargosa Valley, Las Vegas Valley, Mercury Valley, Jackass

Flats, Ash Meadows, Moapa Valley, and Death Valley. It is important to note that the Yucca Mountain drainage basin did not contribute any runoff to the peak flows that occurred in the Amargosa Valley. The draft report for streamflow and precipitation data collected during 1983-85 is about 50 percent complete. Compilation and QA checking of the 1986-90 surface-water records continued.

Activity 8.3.1.2.1.2.2 - Transport of Debris by Severe Runoff. Monitoring of debris movement by surface-water runoff continued. Severe flooding was documented in southern Nevada during June, July, and August, with much of this flooding being urban runoff. Scattered debris-transport events associated with this flooding will be investigated as time allows. Data were analyzed to document the August 1989 event that produced scattered debris transport over a large area, including eastern California and southern Nevada. Data from the event included intensities and cumulative amounts of precipitation from the Project precipitation-gage network and from local residents; indirect estimates of peak flow; and the areal extent, amount, and character of debris deposited by the runoff. Techniques were developed to (1) measure grain size of coarse-grained deposits, and (2) analyze channel cross-section changes. These techniques resulted from literature reviews and work on projects independent of the Project. A lecture was presented at Northern Illinois University describing the effects of accelerated debris transport on fluvial systems.

2.2.1.3 Study 8.3.1.2.1.3 - Characterization of the Regional Ground-Water Flow System

A comment resolution workshop was held in Washington, D.C., to review DOE/HQ and Project Office comments for Study Plan 8.3.1.2.1.3. Revisions to the study plan per this workshop were incorporated, and the study plan was sent to the Project Office on September 17, 1990, for final approval.

Activity 8.3.1.2.1.3.1 - Assessment of Regional Hydrologic Data Needs in the Saturated Zone. An evaluation of this activity was made during the completion of the study plan, in which a prioritization of Project data needs was largely completed. It was determined that as new Project data become available, data needs may change based on previously unrecognized hydrologic conditions. The current data uncertainty was used to prioritize data collection needs, as documented in the study plan.

Activity 8.3.1.2.1.3.2 - Regional Potentiometric-Level Distribution and Hydrogeologic Framework Studies. A reevaluation of planned water-table (WT) holes at Yucca Mountain concluded that three additional WT holes upgradient from the Design Repository Area are necessary to (1) properly specify boundary conditions for models of the site saturated zone; (2) determine the presence or absence of ground-water divides upgradient from Yucca Mountain; and (3) better characterize the large hydraulic gradient located north of the Design Repository Area. A recommendation was submitted to the Project Office by the USGS indicating the needed drillhole locations, the rationale for the holes, and the desired scheduling of these holes.

A technical presentation entitled "Characterization of the Subregional Ground-Water Flow System of Yucca Mountain and Vicinity, Nevada-California"

(Czarnecki) was given to staff of the NPS Water Resources Division in Fort Collins, Colorado. A meeting was later held with NPS staff to review activities in compiling data for a monitoring well program in the northwest Amargosa Desert. An invitation to visit and sample springs in Death Valley National Monument for regional hydrochemical characterization was also extended.

A report on hydrogeologic inferences from drillers' logs and geophysical surveys of the Amargosa Desert was published as a USGS Open-File Report (Oatfield and Czarnecki, 1990).

Activity 8.3.1.2.1.3.3 - Fortymile Wash Recharge Study. A preliminary analysis to determine a correlation integral for mean daily discharges during the period 1965-88 at a USGS gaging station in central Nevada was performed. This analysis indicated a strange attractor with an approximate fractal dimension of 3.9. A strange attractor with fractal dimension indicates chaotic behavior of the system. If the systems governing runoff processes do act in a chaotic manner, then data collection programs should be devised considering chaotic analyses. An abstract entitled "Correlation Integral Analysis of South Twin River Streamflow, Central Nevada: Preliminary Application of Chaos Theory" (Savard) was written, reviewed, and submitted to the American Geophysical Union (AGU) for inclusion in the AGU Fall 1990 meeting. The abstract discusses the method and results of scoping work which applies chaos theory to characterizing Nevada streamflow.

A report entitled "Hydrologic and Drill-Hole Data for Test Wells UE-29a#1 and UE-29a#2, Fortymile Canyon, Nevada Test Site" (Waddell, 1984) was reviewed to determine evidence of recharge in Fortymile Wash. The report indicated high values of tritium (200 pCi/L) in a water sample from UE-29a#1 compared to 37 pCi/L water from deeper UE-29a#2. Hydraulic head in UE-29a#1 was about 4 meters higher than UE-29a#2. These conditions indicate that substantial recharge is likely to be occurring in Fortymile Wash.

Preliminary channel width and depth measurements of the active channel in Fortymile Wash were made, indicating that channel width increases below Fortymile Canyon as Fortymile Wash joins Yucca Wash and Drillhole Wash. The channel width narrows near well J-12. These preliminary data indicate that Fortymile Wash, historically, may have been gaining and losing water along different reaches in the Yucca Mountain area.

No streamflow was observed in Fortymile Wash during the reporting period. Runoff was noted in nearby streams (Topopah Wash and Mercury Valley tributaries). Photographs were taken to document the runoff event, and surface-water personnel were notified.

Activity 8.3.1.2.1.3.4 - Evapotranspiration Studies. A report on hydrologic, meteorological, and unsaturated-zone moisture-content data for Franklin Lake Playa, Inyo County, California, was revised and published as USGS Open-File Report 89-595 (Czarnecki, 1990). The data contained in the report form a partial basis for estimates of evapotranspiration at the playa; these estimates are contained in a companion interpretive report covering the geohydrology and evapotranspiration of Franklin Lake Playa. The latter report received DOE and USGS approval for publication as a USGS Open-File Report.

Project staff met at the NCAR (Marshall Site) near Boulder, Colorado, to examine eddy correlation and Bowen Ratio stations for measuring evapotranspiration to be used as part of the Quaternary regional hydrology studies. Plans to have Project Bowen Ratio stations set up at the same location for side-by-side comparisons of results were discussed.

2.2.1.4 Study 8.3.1.2.1.4 - Regional Hydrologic System Synthesis and Modeling

Study Plan 8.3.1.2.1.4 was technically reviewed and revised by the USGS and submitted to the Project Office on June 6, 1990.

Activity 8.3.1.2.1.4.1 - Conceptualization of Regional Hydrologic Flow Models. An abstract entitled "Possible Effects of a Wetter Climate on the Ground-Water Flow System of Yucca Mountain and Vicinity, Nevada-California" (Czarnecki) was written, reviewed, and accepted for publication in the proceedings of the Geological Society of America (GSA) National Meeting, to be held in Dallas, Texas, Oct. 29-Nov. 1, 1990. The paper was invited for presentation during a special GSA symposium entitled "Transient Responses to Global Change."

An abstract entitled "From Where and By What Flow Paths Does Water Beneath Yucca Mountain, Nevada, Originate?" (Czarnecki et al.) was written, revised, and sent to the AGU for inclusion at the Fall 1990 meeting in San Francisco.

A technical overview of the regional ground-water flow system of Yucca Mountain and characterization activities within the regional saturated-zone studies was presented to a DOE Peer Review Team. Activities that were described included regional potentiometric levels and hydrologic properties, Fortymile Wash recharge, and evapotranspiration studies. A lecture on hydrologic modeling interfaces with climate modeling was delivered at a hydrology/climate modeling workshop at the NCAR. A lecture entitled "Hydrologic Factors Affecting Characterization of Ground-Water Flow at Yucca Mountain and Vicinity" (Czarnecki) was presented to staff from DOE/HQ and Weston (Washington, D.C.).

A talk entitled "Saturated-Zone Ground-Water Flow at Yucca Mountain, Nevada: Can Fracture Flow be Adequately Characterized?" (Czarnecki and Geldon) was presented at the Committee for the Advancement of Science in Yucca Mountain Project (CASY) September symposium entitled "Fractures, Hydrology, and Yucca Mountain." An abstract of the talk also has been prepared for a companion USGS Open-File Report.

A meeting was held by USGS staff to determine the likely success of determining the age of paludal sediments deposited in the Amargosa Desert through uranium series dating. It is unlikely that carbonate cement is sufficient to provide a reasonable age. Root casts exist in the indurated calcrete cap within these sediments, and attempts should be made to locate casts with a carbonate core. Dating of these sediments (which correspond in part with simulated discharge locations under wetter climatic conditions) may be an important part of validating the results of simulations of future ground-water flow.

Activity 8.3.1.2.1.4.2 - Subregional Two-Dimensional Areal Hydrologic Modeling. Tentative technical plans were made to revise the geographic location and type of hydrologic boundaries simulated in previous regional ground-water flow models.

2.2.1.5 Study 8.3.1.2.2.1 - Characterization of Unsaturated-Zone Infiltration

A comment resolution workshop was held September 11-12, 1990, to address Project Office and DOE/HQ comments on Study Plan 8.3.1.2.2.1. The revised Study Plan was resubmitted to the Project Office on September 18, 1990.

The initial meeting of the Peer Review Team on UZ Hydrology at Yucca Mountain, Nevada, was held in Las Vegas on April 23-26, 1990. This team is composed of expert consultants in UZ hydrology and includes R. A. Freeze (chairman), L. G. Everett, G. E. Grisak, J. W. Mercer, R. W. Nelson, S. P. Papadopulos and M. Th. van Genuchten. At this meeting, the Project Office outlined the purpose and scope of the peer review, and team members made presentations on background topics pertinent to the deliberations of the team. A field trip was taken to Yucca Mountain, followed by a day of development of a better understanding of UZ phenomena. Out of these discussions, a list of topics and questions was produced for consideration by Project Principal Investigators (PIs) in UZ studies. Following the meeting, the team members familiarized themselves with publications selected for them by the PIs.

On June 4-8, 1990, the team held a second meeting in Las Vegas. At this meeting, the PIs made presentations on their respective studies and answered the questions provided by the team. Following these presentations and ensuing discussions, Alan Freeze (team chairman) presented the preliminary conclusions and recommendations of the peer review.

The Peer Review Record Memorandum was received from the team on September 15, 1990. The PIs are currently in the process of responding to the conclusions and recommendations of this document.

Activity 8.3.1.2.2.1.1 - Characterization of Hydrologic Properties of Surficial Materials. In an attempt to better understand the surficial materials on Yucca Mountain and surrounding watersheds, a statistical point count technique was begun in order to determine the percent of the surface area of each microgeologic unit shown on published geologic maps. The point counts are done on 400-foot centers. The larger watersheds generally require about 2500 points, thus giving statistically meaningful results. In addition to the point counts, several ridge-to-ridge transects were made to determine in detail the nature of the surface material shown on published geologic maps. It has been found that rarely is the surface exposed bedrock. More frequently it is covered by float or debris of varying thicknesses. This cover will certainly contribute to the infiltration characteristics, thus further complicating the quantitative definition of hydrogeologic units.

A survey with a surface-based, very low frequency (VLF) electromagnetic geophysical tool was conducted over the same area that was previously surveyed with an EM-34 and ground penetrating radar (GPR). Preliminary analysis suggests that the electromagnetic ground conductivity (EMGC) techniques (VLF

and EM-34) may be useful for measuring relatively shallow conductivity contrasts like the tuff/alluvium contact. The EMGC surveys were generally more successful than GPR in penetrating soil horizons and clay layers found in the alluvium at Yucca Mountain. Additionally, the EMGC techniques did not experience severe problems with radio frequency interference as did GPR.

Several tours of the HRF in Area 25 were conducted. The participants were the DOE-appointed UZ Hydrology Peer Review Team, SNL performance assessment modelers, several journalists from the Las Vegas Review-Journal newspaper, and Stripa, which is an international group of scientists dealing with nuclear waste disposal.

Research presentations have been prepared and given to the UZ Peer Review Team and the NRC. The Peer Review Team was given an overview of the characterization of surficial materials. The NRC was also presented an overview with particular emphasis on spatial variability of surficial materials. This presentation was provided in the format of a DOE-NRC technical exchange.

Activity 8.3.1.2.2.1.2 - Evaluation of Natural Infiltration. The ongoing program for monitoring natural infiltration in the shallow UZ continued through neutron moisture meter logging of 74 shallow, cased boreholes. Each hole is logged to its total depth (or 50 feet in deeper holes) once each month. This data base has continuous records for over six years.

Work was initiated on a paper presenting laboratory data that demonstrate the degree to which temperature changes on both up-hole and down-hole components of the Campbell Pacific Nuclear moisture meter cause measurement errors.

Work continued on a journal article on the spatial variability of solar radiation at Yucca Mountain. Because the number of measurements necessary to accurately characterize the solar radiation at Yucca Mountain would be prohibitive, a regional topography model and modeling strategy must be developed. Determining the spatial variability is the first step to developing such a model.

Several activities have been ongoing in support of the water budget studies. There has been considerable effort put into understanding and improving procedures for using tipping-bucket rain gages. A calibration curve, based upon the rate of rainfall, is being developed for each individual instrument. This calibration is particularly important in this climate where rainfall rates vary widely. Prototype testing of equipment and methods to measure evapotranspiration (ET) using Bowen Ratio and eddy correlation continued. These techniques require a very accurate determination of solar and terrestrial radiation balance. Precise measurement of each component of the radiation balance equation continued at a site on Jackass Flats. To optimize the deployment of multiple sites around Yucca Mountain, an extensive, high quality array of instruments is being used to test single, less expensive instruments. Monitoring continued at a Class A evaporation pan on Jackass Flats. The rates measured here will be compared with estimates of actual ET close by to help further the understanding of these arid land processes. It has been determined that very high advection in this environment may limit the use of the evaporation pan to provide only the absolute upper limits of ET.

A prototype radio telemetry system was deployed for two existing weather stations on Yucca Mountain. This system facilitates real-time monitoring of weather conditions at remote sites.

A project to determine the feasibility of continuously monitoring moisture conditions in a shallow (<50 feet) borehole in unconsolidated alluvium was undertaken in Topopah Wash near Test Cell "C". A previously-drilled hole in the channel bottom was instrumented with temperature and pressure sensors and Peltier-type thermocouple psychrometers. Inflatable packers were used to isolate successive intervals. Unexpected problems were encountered when some of the packers were punctured in the borehole when inflated. However, monitoring by an automated data collection system has continued since the packer located at the top of the borehole has maintained enough pressure to isolate the borehole from direct atmospheric changes. A second hole was drilled using techniques developed for emplacing small diameter instrumentation tubes. This hole was drilled to >30 feet depth with a hand held jackleg drill. The small diameter instrument tube will allow access to the subsurface with a neutron moisture meter without disturbing the instrument string in the original borehole.

A heated, tipping-bucket snow gage was installed near USW-UZN2 and an instrument for sensing the presence of water was placed in the bottom of the drillhole. It has been observed that, after certain precipitation events, water has appeared in the bottom of the hole. The purpose of the instrumentation is to attempt to better understand the infiltration processes which cause this event.

Research presentations have been prepared and given to the UZ Hydrology Peer Review Team and the NRC. The Peer Review Team was given an overview of the natural infiltration activities. The NRC was also presented an overview of the natural infiltration activity with particular emphasis on the characterization of spatial variability of natural infiltration. This presentation was provided in the format of a DOE-NRC technical exchange.

Activity 8.3.1.2.2.1.3 - Evaluation of Artificial Infiltration. Work was begun to estimate infiltration and evaporation conditions that will exist on the small infiltration plots using a Richard's-equation-based flow model. Saturated and unsaturated hydraulic conductivity and water retention characteristics for the soil will be estimated using soil texture data from sieve and hydrometer analyses. These measurements will help determine the duration of the experiments and the instrumentation needs.

An overview of the artificial infiltration activities was presented to the UZ Hydrology Peer Review Team. It was also presented to the NRC, with particular emphasis on the infiltration under wetter climatic conditions. This presentation was provided in the format of a DOE-NRC technical exchange.

2.2.1.6 Study 8.3.1.2.2.2 - Water Movement Tracer Tests

Activity 8.3.1.2.2.2.1 - Chloride and Chlorine-36 Measurements. Prototype drilling at Apache Leap, Arizona, was completed, and dust samples for ^{36}Cl analyses were collected. Water samples from perched water zones and the water table were collected by Sample Management Facility (SMF) staff.

These samples were transported to HydroGeoChem in Tucson for storage and eventual processing and analyses. Plans for sampling deep alluvium on the NTS for ^{36}Cl analyses are being developed in conjunction with SNL as part of a collaboration with the Greater Continent Disposal Project. It is planned that field samples for the SNL study will be used for prototype testing of procedures for collection, processing, and analysis of soil and rock samples for chlorine isotopes to be used in the analogous site characterization efforts.

During the preparations for the Los Alamos National Laboratory (LANL) QA audit of HydroGeoChem scheduled for August 13, it was realized that the HydroGeoChem QA program did not meet the requirements of the LANL-Project QA program. Subsequently, a stop work order was issued for HydroGeoChem's technical activities. The company agreed to work under the LANL-Project QA program, and steps are being taken to bring them under this program and lift the stop work order.

A paper entitled "Chlorine-36 Studies of Water Movement Deep Within Unsaturated Tuffs" was presented by A. E. Norris at the Fifth International Conference on Accelerator Mass Spectrometry in Paris, France, on April 26. This paper will be published in Nuclear Instruments and Methods in Physics Review B.

2.2.1.7 Study 8.3.1.2.2.3 - Characterization of Percolation in the Unsaturated Zone--Surface-Based Study

DOE audit review of Study Plan 8.3.1.2.2.3 was completed on September 18, 1990. Author response to the audit review is in progress.

Activity 8.3.1.2.2.3.1 - Matrix Hydrologic Properties Testing. Mathematical models from soil science literature describing relative water permeability and moisture retention characteristics are being evaluated for use in tuffaceous rocks. Parameters from these equations will be used in larger scale models, such as modeling imbibition.

Laboratory experiments of water imbibition into rock core are being simulated with the use of the TOUGH code. Imbibition is an easily measured unsaturated flow phenomena. The model requires relative water permeability and moisture retention characteristic functional relationships as input. By modeling imbibition, a tool is used to select appropriate methods of measurement as well as equation formulations. Sensitivity analyses can be conducted to identify parameters that must be estimated with improved uncertainty. From preliminary modeling, it appears that modeled imbibition is very sensitive to the absolute magnitude of the saturated water permeability.

A study has been initiated to characterize one-dimensional horizontal variability on Yucca Mountain. Rock outcrop samples were collected every 10 meters along a transect of the Pah Canyon Member of the Paintbrush Tuff. Physical property measurements (bulk density, porosity and water content) and flow measurements (imbibition, saturated hydraulic conductivity, air permeability) are being conducted on these samples. These data will then be used in a geostatistical model for the analysis.

Rock outcrop samples were collected from Yucca Mountain and sent to a laboratory under contract to study the behavior of zeolites when dried under different conditions. Physical property measurements will be conducted along with observations of thin sections (with the use of a scanning electron microscope (SEM)) after samples are dried in either a relative humidity oven at various humidities or a standard oven at 105°C. It is anticipated that the structure of the zeolites will be irreversibly changed when dried in a standard oven, but unaltered when dried in a relative humidity oven. This structure change will influence properties such as porosity that are determined at oven dry conditions.

This study is attempting to better define the appropriate oven drying techniques to be used for hydrologic analysis while maintaining in situ pore geometry and flow channels.

Sample handling procedures at the Apache Leap prototype drilling site were evaluated and recommendations were made concerning the matrix-hydrologic property activity requirements. Some core from this site has been received from the SMF. These samples are being used to (1) test liquid saturation procedures, (2) understand the change in matrix structure with change in water content relationship (due to presence of zeolites), and (3) supply data for calibration of geophysical tools.

Research presentations have been prepared and given to the NWTRB, the UZ Hydrology Peer Review Team and the NRC. The NWTRB was given a presentation on results from the G-Tunnel prototype drilling study (wet versus dry drilling). The Peer Review Team was given an overview of the matrix-hydrologic property activity. The NRC was also presented an overview of the matrix-hydrologic property activity, with particular emphasis on the characterization of spatial variability and representativeness of core samples. This presentation was provided in the format of a DOE-NRC technical exchange.

A data report titled "Preliminary Permeability and Water-Retention Data from Nonwelded and Bedded Tuff Samples, Yucca Mountain Area, Nye County, Nevada" (L. E. Flint and A. L. Flint) received conditional USGS Director's approval. An abstract titled "The Influence of Scale on Sorptivity Values from Imbibition Experiments on Welded and Nonwelded Tuff" (A. L. Flint) was submitted for presentation at the Nuclear Energy Agency Workshop on Flow Heterogeneity and Site Evaluation in Paris, France. A draft of the write up for INTRAVAL Test Case 12 for the final report for Phase I was prepared and sent to the NRC for compilation. The report will include a presentation of the data that will be available, when requested, for model validation being done by the INTRAVAL committee. The data will include drilling logs; geophysical logs; physical property measurements on core; field and laboratory imbibition measurements; and borehole instrumentation measurements of temperature, pressure, and water potential.

Several tours of the Hydrology Laboratory in the HRF were given. These tours included measurement demonstrations. A group of UZ modelers composed of Project participants toured the facility, indicating interest in the imbibition experiments. The UZ Hydrology Peer Review Team was given the opportunity to tour the laboratory and evaluate measurement procedures and discuss concepts. Tours were also given to a group of Congressional staffers

and to Stripa. The NWTRB also requested a personal field trip for two members to Crater Flats and Solitario Canyon to study local geology. Pan Am World Services, Inc. video specialists toured the laboratory and used it for filming activities that will be used for QA Training Videos at the NTS.

Activity 8.3.1.2.2.3.2 - Site Vertical Borehole Studies. The Project Office concluded field operations of Phase 1e of its prototype drilling program on June 23, 1990. Two boreholes were drilled near Superior, Arizona, utilizing the permit issued by the Globe Ranger District of the U.S. Forest Service for the Apache Leap site. Phase 1e successfully demonstrated the capability of a multicomponent system designed for dry drilling/coring to acquire uncontaminated samples at depth while minimizing borewall contamination. Cores and samples were collected from a maximum depth of 1713 feet.

The prototype drilling program was designed to utilize government-owned equipment and the Lang Exploratory Drilling LM-120 drilling rig, the largest rig for dual-wall dry drilling and coring. The program consisted of (1) drilling and coring a 12¼-inch diameter borehole to approximately 1100 feet, (2) continuing to drill/core from 1100 feet to 1700 feet in a 9½-inch diameter borehole, and (3) skidding the rig and drilling/coring an 8-inch diameter borehole to 223 feet. The program at Apache Leap tested the small LM-120 rig to its depth/weight design limits.

The larger dual-wall system successfully recovered PQ core (3.3-inch diameter) from the 12¼-inch diameter borehole to a depth of 1108 feet. The smaller system successfully recovered HQ core (2.4-inch diameter) from a 9½-inch diameter borehole to 1713 feet.

Use of compressed air in conjunction with a vacuum system for borehole cleaning and dust control was successfully tested during the dry portions of the drilling. Some dust was occasionally noted in the system exhaust due to inefficiencies in the water spray system with the separator. Further work on this system will focus on improving efficiency of the dust separator over a wider range of operating conditions and reducing the total space required for the drilling/sampling system.

Drilling and coring of unsaturated volcanic tuffs was successful down to a depth of 362 feet, where a perched-water zone was encountered. Dry drilling operations were hampered until a containment pipe (casing) was set at 1107 feet. The water containment technique was a qualified success; a small amount of water continued to seep into the hole during subsequent deepening of the first borehole. Borehole television camera pictures ultimately revealed two small leaks in the casing.

The water encroachment was so minute that it did not affect the drilling and coring operation below 1107 feet. Conditions at the bit face were as dry as the rock being drilled. However, the continuous inflow of water into the borehole from the casing leaks above resulted in the cores becoming more or less contaminated with water while being retrieved to the surface after being drilled.

Because of the contamination of the cores, the geophysical logging program for calibration of density logs and for scoping the modern Geochemical Log was canceled.

In addition to the Phase 1e Program objectives, the following significant observations were made:

1. Coring with air on high humidity days resulted in water condensation on the core. This could compromise the core for hydrologic and geochemical studies. Design guidelines are being developed for equipment to ensure condensation is eliminated during coring.

2. A tungsten carbide "drag bit" design was found effective for coring the softer parts of the formation at shallow depths. The design produced high penetration rates, low coring pressures, and less condensation.

3. Limited "fishing" (recovery of lost drilling equipment downhole) is possible with the present dual wall system. This process was tested successfully during Phase 1e operations when a core barrel was recovered.

Phase 1e activities at Apache Leap have shown that the dual-wall drilling/coring system can provide samples and boreholes suitable for site characterization. Information obtained during this program should provide a basis for future prototype drilling with the larger LM-300 drill rig acquired by the government in August 1990. Design specifications of the LM-300 include drilling depths of 2700 feet with a 9½-inch diameter borehole and 4100 feet with a 7-inch diameter borehole.

Preliminary tests of a gas sampling system were conducted. This system is designed to withdraw vapor-saturated gases from deep UZ borehole instrument stations without condensing water vapor in the sampling tubes. These tests were conducted at the HRF sensor-calibration laboratory using a simulated instrument station to provide a constant supply of vapor saturated air. The sampling system utilizes a dry carrier gas, N2, that is mixed with vapor-saturated gases at the instrument station. The N2 lowers the source gases' dew point temperature to a temperature that is lower than any temperature that will be encountered by the gas mixture as it moves from deeper, warmer depths to the sample collection point (cooler environment) at the ground surface. This system eliminates gas sample contamination resulting from fractionation of heavy oxygen and hydrogen isotopes. Because all mass is conserved, the sampling procedure is also being used to calculate the dew point temperature of the source gas and thus provide an independent means of verifying the accuracy of the downhole thermocouple psychrometers. Additional testing and evaluation will be conducted over the course of the coming year. One of the objectives of future testing is to design and configure a manifolding system that will allow multiple stations (up to five) to be pumped simultaneously, using a single dew point hygrometer located at the ground surface to monitor the dew-point temperature of the gas mixture.

A prototype downhole instrument station apparatus (DISA) was designed and constructed. This device, made entirely of low thermal conducting materials (plastics), houses the instrument station sensors (thermistors, pressure

transducers, and thermocouple psychrometers) and control devices (2-way and 3-way solenoid valves). It contains all the internal plumbing needed to sample deep borehole gases (see discussion above) and to isolate the pressure transducers for in situ recalibration. Fifteen DISA units will be built over the next several months. These will be tested and evaluated as part of a long-term program to characterize sensor stability characteristics in a downhole environment. A project proposal was submitted (and tentatively approved) to instrument three shallow (40 feet deep) boreholes that will be located next to the HRF's sensor calibration laboratory. These boreholes will be instrumented using a modified version of the deep UZ borehole solid stemming design that will permit periodic recovery of the downhole sensors for laboratory evaluation. This test bed complex will be operated for the duration of the UZ instrumentation and monitoring program.

A three-month experiment was conducted to evaluate the early time drift characteristics of the Druck PDCR 930 pressure transducer. These tests were conducted in constant temperature baths located at the HRF's sensor calibration laboratory. The results of these tests are currently being evaluated. Preliminary results indicate that these semiconductor pressure transducers are sufficiently conditioned (burned-in) at the manufacturer's facility to suppress early time drift problems that are normally associated with new (and especially metal-foil) transducers.

Two second-order polynomial regression models were successfully fitted to the pressure transducer and thermocouple psychrometer calibration data. These models permit definition of accuracy at two sigma significance that is better than 0.03% full scale for the pressure transducers; and better than 10% at -1.0 bar, and 2% at -75 bars of water potential. Preliminary evaluations of a newly-designed nanovoltmeter with an internal, buffered memory system were conducted. This device will be marketed in early 1991 and is being considered as a cost-effective replacement for the current nanovoltmeter which requires a dedicated micro-computer for scanning the output of the thermocouple psychrometers.

An overview of the Unsaturated Zone Borehole Drilling and Instrumentation program was presented to the Unsaturated-Zone Hydrology Peer Review Team in Las Vegas during the first week of June. A second presentation describing the Deep Borehole Testing program to characterize UZ flow processes was presented to the NRC in Denver during the last week of September.

A report documenting geohydrologic data from test hole USW UZ-7 drilled several years ago at Yucca Mountain was published by the USGS (Kume and Hammermeister, 1990).

Two critical, capital equipment purchases were processed during the reporting period: one for a precision, primary standards dead-weight tester that will be used to support calibration of the pressure transducers, and the other for an alternating current (AC) power conditioning system to provide regulated AC power to the HRF sensor calibration laboratory. The AC power conditioning system is needed to overcome problems with sensor calibrations (primarily the thermocouple psychrometers) caused by unstable line power into the HRF. An exhaustive market survey was conducted to locate a two-pressure humidity generator with sufficient precision and accuracy to maintain the

calibration of the dew point hygrometers that will be used in the gas sampling program.

Temporary hardware modifications were made to the GemLink modems used as part of the prototype Integrated Data Acquisition System (IDAS). The fix was successful in solving communication problems between the field site computers and the archiving computer. Solving these communication problems was a significant and important breakthrough for the IDAS program, which successfully demonstrated the feasibility of using a synchronous, multidrop communications network. The entire topology of the IDAS hardware/software configuration has been designed around the multidrop communications concept. The fix, however, is not considered adequate to support quality-related activities. It will be necessary to find a replacement system for the GemLink. A market survey was initiated to locate a suitable replacement modem. In the absence of an adequate replacement, the temporary fix has allowed other prototype work to proceed.

Two IDAS technical procedures (HP-135, "Procedure for IDAS Development -Writing, Controlling, Testing, Implementing, and Documenting IDAS Software and Control Files"; and HP-151, "Procedure for Software Installation, Operation, and Maintenance") were forwarded to the QA office for technical review and verification of compliance with QA procedures.

Work was done to identify design and construction deficiencies in the temperature-control and plumbing system of the prototype instrument shelters for the UZ-9 and UZ-4 boreholes. However, no work has been done to finalize a design for the IDAS field shelters. This is a major issue for successful completion of IDAS developmental work prior to start of new surface-based drilling and testing.

The geophone cable assemblies, for vertical seismic profiling (VSP) investigations at the UZ-9 complex, were delivered to the NTS in May. These were manufactured under contract to the USGS by Litton Resources Systems of Houston, Texas.

Several VSP papers were presented at various professional meetings during the reporting period. These included "Seismic Cross-Borehole Imaging of the Near-Surface Using Tomography and Prestack Migration in Elastic and Physical Models" (Balch et al.) (presented at the 1990 meeting of the Society of Exploration Geophysicists) and "The Use of Forward and Back Scattered P-, S- and Converted Seismic Waves in Cross-Borehole Imaging" (Balch et al.) (presented at the 1990 meeting of the European Society of Exploration Geophysicists).

Several research theses were submitted for publication as Water Resources Investigation Reports. These reports deal with the use of reverse time migration to image the subsurface with a method of separating P- and S- waves from field seismic records.

Software for VSP modeling of Yucca Mountain was transferred to the Florida State University Cray computer system. Software transfer included raw data files of the Yucca Mountain physical model. All future work on subsurface imaging will be done either on the Cray supercomputer at Florida

State University or on newly installed IBM Risc 6000 computer workstations at the Colorado School of Mines.

The 8-inch diameter straddle-packer system is being redesigned for use in 12-inch diameter holes. The 12-inch system will be capable of performing the same air permeability testing as the 8-inch system. Construction of the 8-inch packer assembly is 60% complete. The packers and subconnections are complete, along with the electrical connectors and gas plumbing. The support trailer was purchased, and the design of the attached field office, boom, winch, and power system has been completed. All electrical wire and gas tubing has been purchased. Prototype gas permeability testing was conducted at the NRC-University of Arizona Apache Leap Test Site (ALTS) near Superior, Arizona. These tests will aid in selection and development of the test methods for use at Yucca Mountain (see Activity 8.3.1.2.2.4.4, "Radial-Borehole Tests in the ESF").

Abstracts of presentations titled "Thermodynamic Processes of Liquid and Vapor Movement in the U12g-12 Drift Extension, G-Tunnel, NTS" (Rousseau and Thordarson, 1990) and "Determination of Unsaturated-Zone Permeability and Storativity Using In Situ Gas Injection Tests, Apache Leap Tuff Site, Arizona" (Trautz, 1990) were published in the Proceedings of the American Institute of Hydrology (AIH) Spring Meeting.

2.2.1.8 Study 8.3.1.2.2.4 - Characterization of Percolation in the Unsaturated Zone--ESF Study

Study Plan 8.3.1.2.2.4, containing activity descriptions for construction phase ESF testing, was submitted to the NRC on February 9, 1989. Activity descriptions for MTL ESF tests are in preparation.

Activity 8.3.1.2.2.4.1 - Intact-Fracture Test in the Exploratory Shaft Facility. A paper entitled "Assessment of Fracture Sampling Techniques for Laboratory Tests on Core" (Severson) was submitted for the 1991 International Topical Meeting on High Level Radioactive Waste Management, to be held April 28 through May 2, 1991, in Las Vegas. Drafts of the technical procedure for collecting intact radial core fractures and of a preliminary letter report on prototype intact fracture sampling methods were begun.

Development of the Moire projection methods for fracture profile characterization continued. Significant progress included receipt of the imaging board which allows processing and display of video data, calibration of the system using various objects of known geometry, development of a computer model simulating the optical table and equipment set up, use of image digitization and processing to view Moire fringes, and evaluation of methods to provide National Institute of Standards and Technology (NIST) traceable standards. Technical staff traveled to Texas Tech University to evaluate progress in the Moire projection study and to plan for ongoing work in FY 91.

Various equipment maintenance was conducted within the laboratory, including evaluation of a corrosion problem in the vacuum oven cold trap. Laboratory analyses indicate the presence of a low pH, high chloride solution in the trap which appears to be responsible for the corrosion. Further evaluation of the source of this contamination is being conducted.

All DEC-based computer equipment was inventoried and transferred to another activity because the data acquisition equipment for the Fracture Rock Hydrology Project will all be IBM compatible. The Tektronix 469DX color printer and Mirage software, which will be used for color copies of the Moire projection data, were installed and debugged. Drawings were made to be used for cost estimates for construction of the confining vessel for stress permeability tests on axial fracture samples. The proposed design should considerably decrease the cost of the confining vessel over those which are commercially available.

The ESF Test Description Document was reviewed. Seventeen alternative options for the ESF were evaluated. Several meetings concerning design options and alternative construction methods were attended and technical advice given. Responses to the "Categorization of ESF Tests Table" were provided to the ESF alternatives committee.

Activity 8.3.1.2.2.4.2 - Percolation Tests in the Exploratory Shaft Facility. A paper entitled "An Alternative Method to the Mariotte Reservoir for Maintaining a Constant Hydraulic Pressure" (Thamir) was submitted to the 1991 International Topical Meeting on High Level Radioactive Waste Management to be held in Las Vegas April 28 through May 2, 1991.

Tests were initiated to identify the proper probes and shielding necessary to use time domain reflectometry to measure moisture content in fractured-welded and nonwelded tuff. Dry-cut rock slabs were taken to the University of Colorado for estimation of the attenuation factor for gamma radiation work. The mass attenuation factor is needed to calculate the size of the source used for gamma density measurements on laboratory samples. Results of resistivity work conducted during 1989 were evaluated. Conductivity rings were constructed for measurement of tracers during inflow/outflow studies. Corrosion was found to affect both conductivity probes and tensiometer tips. Measures have been taken to overcome this problem.

Thermocouple psychrometers, air-injection strings, and tensiometer/ transducer systems were modified to pack off sections of interest rather than measuring an average over the entire length of a borehole. The packers were satisfactorily compliance-tested. A data-logger program to read four psychrometers every two hours was written to monitor moisture changes during a ponding study. A statistical spreadsheet was developed for psychrometer data.

Imbibition tests were conducted on an unsealed unwelded core. The core was then sealed to study the effects of trapped air during imbibition. Porosity measurements and air and water permeability measurements were also made.

Relations between water content and water potential were determined, and porosity measurements were made in preparation for a ponding test on Block "D", a block of welded tuff of approximately 16 x 16 x 13 centimeters in size. The hardware and software needed to operate the infusion pump used to control boundary flux were completed. Block "D" was field-saturated by ponding water on the block surface. The study was terminated after ponding water for more than two months with no flow observed from the block during that time.

Activity 8.3.1.2.2.4.3 - Bulk-Permeability Test in the Exploratory Shaft Facility. Seventeen options for redesigning the ESF were evaluated, and comments were presented to the ESF Alternative Methods Committee. Concern was also expressed that alternative construction methods ensure the necessary level of fracture mapping detail at the test locations. Several ESF Calico Hills alternative meetings were attended and input to the decision-making process given. No significant effect to the Bulk Permeability Test is anticipated as a result of the alternatives presented other than the potential of relocating test locations for the four planned tests.

The draft of the Test Description Document for Test No. 24, Bulk Permeability, was reviewed and preliminary comments were drafted. Finalization of this document was suspended pending selection of ESF design and construction methods.

Activity 8.3.1.2.2.4.4 - Radial-Borehole Tests in the Exploratory Shaft Facility. Construction of the redesigned prototype cross-hole testing straddle packer systems (AZ-2) was completed. Modifications include new electronic connectors, submodifications, inflation line plumbing, and data acquisition system.

A newly designed and constructed Mass Flow Controller system was tested and, with minor modifications, found to be working. This unit allows gas flows to be regulated at rates from 1 to 750 standard liters per minute. This system will be used in several air permeability testing programs.

The prototype Data Acquisition System (DAS) was modified, and new software was written for the pressure transducers, thermistors, and thermocouple psychrometers (TCP). A computer program for calculating strike and dip, based on three-point depth measurements from boreholes, was developed and used to analyze the television logs from the ALTS. This data was then used in prototype testing at the ALTS.

Prototype testing with the AZ-2 packer assemblies was conducted at the ALTS during May and July 1990. Testing includes single and cross-hole gas injection using air and nitrogen gases. A new gas saturator was used to raise the relative humidity of the air and allow comparison of wet and dry injection methods. The AZ-2 system performed very well, and the DAS and measurement equipment (pressure transducers, thermistors and TCP) all worked well. Those items that failed (two pressure transducers and one TCP) were returned to the manufacturers for analysis in hopes of preventing future failures.

Analysis of the ALTS test data will continue through the winter. Several different analysis methods will be used in hopes of determining the most applicable methods for fractured volcanic tuff.

A presentation on the ALTS prototype testing was given at the June meeting of the UZ Hydrology Peer Review Team and at the September NRC/DOE technical exchange.

Activity 8.3.1.2.2.4.5 - Excavation-Effects Test in the Exploratory Shaft Facility. Seventeen options for alternative ESF designs were evaluated and comments were presented to the ESF Alternatives Committee.

Staff participated in several meetings in which ESF design options and construction methods options were discussed. Potential impacts to the Excavation Effects Test were evaluated, and input was provided to the appropriate committees. A portion of the input was provided as a table entitled "Categorization of ESF Tests Table."

The draft Test Description Document text for the Excavation Effects Test was reviewed. The document was subsequently tabled pending selection of an ESF alternative design and construction methods. No other technical work on this activity was conducted due to prioritization from the Project Office.

Activity 8.3.1.2.2.4.7 - Perched-Water Test in the Exploratory Shaft Facility. A paper entitled "Perched-Water Prototype Testing: Evaluation of Detection, Borehole Coring, and Hydrologic Monitoring Techniques" (Chornack and Marvil) was submitted for inclusion in a USGS Bulletin.

Additional testing was conducted with the USGS-designed and -built inflatable packers. Packers salvaged from G-Tunnel were field-tested as part of a redesigned instrument system. Five out of six packers burst when inflated. Results of this test indicated that the commercially produced "MOSDAX" system, by Westbay, might be the preferred packer-instrument system for perched-water testing and monitoring. Design work on collection and sampling equipment for use in the ESF continued.

Activity 8.3.1.2.2.4.9 - Multipurpose-Borehole Testing near the Exploratory Shafts. Packer-instrument system design and development continued for air permeability testing and gas sampling in the multipurpose boreholes. Preliminary testing of this equipment was conducted at the ALTS. Based on results of this testing, the equipment will be modified as needed.

Prototype dry-drilling and dry-coring was conducted by the Project Office near Apache Leap. Two boreholes were completed, one deep borehole to test the capabilities of the drilling system and another shallow borehole for prototype gas sampling experiments. The USGS interacted with SMF personnel to develop and refine sample handling and processing procedures for in situ UZ core samples. Laboratory tests are being conducted on these samples to determine the hydrologic properties. Different methods of core packaging will be evaluated for effectiveness of preserving in situ hydrologic properties. Dry-drilling and dry-coring operations were observed by visiting USGS personnel who had participated in dry, UZ drilling and coring operations on the NTS. This gave the USGS staff an opportunity to compare the various methods being tested.

A perched-water zone encountered at the prototype drilling site was cemented off to attempt dry-drilling and dry-coring below that zone. TV camera logging and caliper logging were conducted in the completed boreholes.

2.2.1.9 Study 8.3.1.2.2.5 - Diffusion Tests in the Exploratory Shaft Facility

Project Office and DOE/HQ review comments on the study plan were addressed, and a comment resolution meeting was held on August 28, 1990, which resolved all comments.

Activity 8.3.1.2.2.5.1 - Diffusion Tests in the Exploratory Shaft Facility. A. E. Norris, the previous principal investigator, was reassigned April 30, and I. Triay became the principal investigator for this study.

The ESF Coordination Committee convened on April 30 at USGS-Denver to review options for shaft construction and to discuss the implications for tests planned in the shaft. Diffusion staff presented an overview of the requirements for the diffusion tests planned in the ESF and provided detailed reviews of the construction options with respect to possible impacts on diffusion studies.

Diffusion staff also participated on a committee to design a tracer system plan for the Project. The committee produced a draft document to describe the system for controlling and coordinating the selection and use of tracers by participants.

2.2.1.10 Study 8.3.1.2.2.6 - Characterization of Gaseous-Phase Movement in the Unsaturated Zone

Author response to Project Office and DOE/HQ comments on Study Plan 8.3.1.2.2.6 was completed, and the revised study plan was resubmitted to the Project Office on May 24, 1990. A DOE audit review was completed on September 28, 1990.

Activity 8.3.1.2.2.6.1 - Gaseous-Phase Circulation Study. No additional field data were collected. Analysis of past data continues.

The data measurement and storage equipment used to date was returned to manufacturers or laboratories for final calibration. The QA staff began reviewing the gas chromatograms and lab notes to ensure the data will meet QA standards for site characterization. All raw data cassette tapes were processed and scanned for incomplete data sets, missing data, and changes in format.

A presentation on the work to date was given at the June meeting of the UZ Hydrology Peer Review Team.

An abstract of a presentation titled "Topographically Affected Air Flow through Yucca Mountain, Nevada" (Weeks) was published in the proceedings of the AIH Spring Meeting.

2.2.1.11 Study 8.3.1.2.2.7 - Hydrochemical Characterization of the Unsaturated Zone

Comment resolution arbitration and audit review of Study Plan 8.3.1.2.2.7 were completed on July 13, 1990. The study plan was approved by the Project Office in September 1990 and forwarded to DOE/HQ for transmittal to the NRC.

Activity 8.3.1.2.2.7.1 - Gaseous-Phase Chemical Investigation. Borehole gas sample collection using direct flow-through containers for carbon-isotope analyses was investigated in the laboratory. In the past, gas samples were flowed through silica gel and collected in molecular-sieve for this analysis.

Preliminary results indicated that (1) silica gel could absorb CO_2 gas at room temperature to some extent, even at low concentrations; and (2) silica gel preferentially absorbed the heavier carbon isotope. Therefore, the new method of collection, without silica gel, yields a more consistent $^{13}C/^{12}C$ ratio. This method will also reduce field pumping time from two days to one-half day.

Pore gas squeezed from UE-25 UZ#5 cores indicated no trace of the tracer gas, SF_6, was trapped inside the cores. This would imply that drilling air did not contaminate the core samples.

A tracer injection system designed by Fenix and Scisson of Nevada was tested at the USW UZP-4 prototype drillhole at Apache Leap on May 16-17, 1990. The injection system could only be operated below 250 pounds per square inch (psi) air pressure in the compressed-air line because of a limitation on the pressure gage. Some core bits would cause the air pressure to increase to 350-400 psi, depending on the bit used. The preliminary results of the tests indicated the tracer was well-mixed at the hole outlet at 1000 feet depth, while not well-mixed near the hole inlet. The installation of a baffle inside the air pipe near the tracer inlet might help the mixing of gases.

A downhole packer system designed and built by the U.S. Bureau of Reclamation (USBR) for gas sampling was smoothly installed at the 8-inch diameter, 220-feet deep prototype hole (USW UZP-5) at Apache Leap on June 24, 1990. The three packers were inflated to 50 psi on June 25, 1990. The pressure drop was only one psi after two weeks and approximately four psi after three months. Packer leak tests were conducted in mid-September 1990 with SF_6 and no leaks were detected.

Removal of drilling air from the 8-inch diameter borehole at the site started on June 25, 1990. Four zones were separated with inflatable packers. Rotary vacuum pumps at a pump rate of 30-50 liters per minute were used to pump the downhole gases. It took nearly 26 days of continuous pumping to bring down the SF_6 concentrations to environmental level.

When the packer system was pulled out of the hole on September 27, 1990, it was found that moisture condensation was occurring on the surface of the aluminum casing (5-inch diameter) connected between the packers. This would result in fractionation of water vapor, and therefore change the δ18D and δD values. Improvements, such as using nonmetal casing or a heating system, are planned to prevent moisture condensation.

Activity 8.3.1.2.2.7.2 - Aqueous-Phase Chemical Investigation. A newly acquired liquid scintillation counter, Quantulus 1220, from LKB Pharmacia of Finland was installed by factory experts during the week of July 23, 1990. The counter was set up and calibrated to count tritium and carbon-14 in samples of water. Background tritium and carbon-14 samples have been counted to check the long-term stability of the instrument. Preliminary results indicated that background was a factor of 4 to 5 lower than other liquid scintillation counters, which would improve the precision of the tritium and carbon-14 data.

An abstract of a presentation titled "Comparison of Pore-water Extraction by Triaxial Compression and High-Speed Centrifugation Method" (Yang et al., 1990) was published in the Proceedings of the AIH Spring Meeting.

Investigations into the means of preserving core samples to prevent changes in water content or gas and water chemistry prior to extraction and analysis continued. About 15 welded and 15 nonwelded cores of varying moisture content from the NTS were weighed on an intermittent basis for a period of two years. About 45 welded cores of variable moisture content from the Apache Leap prototype site were sealed by eight different methods and weighed; they will be weighed intermittently in the future.

Statistical sensitivity analyses to determine the capability of the Dionex ion chromatograph method used to distinguish small differences between boron concentrations showed that the measurement error is statistically less than 0.4%. The boron adsorption analyzed by the ion chromatograph method indicated only slight adsorption by tuff materials. Tuff samples were prepared for and analyzed by SEM to determine the physical effect of contact of the tuffs with solutions during dissolution tests.

New Mexico Institute of Mining and Technology reports on lab column tracer tests were completed. Reports are undergoing technical review prior to acceptance. A first draft of a proposed USGS Water Supply paper titled "Borate Adsorption by Some Volcanic Tuffs: Evaluation of Borate as a Potential Tracer for Unsaturated Flow at Yucca Mountain" (Lewis-Russ) was completed. Additional reports to be submitted for conference presentation or journal publications are "Silica Analysis for Colloid Determination" (Lewis-Russ et al.), "Zero Point of Charge" (Lewis-Russ), and "Boron Adsorption Models Literature Review" (Lewis-Russ and Langmuir).

Optimal rubble size prototype testing continued. About 30 nonwelded-tuff core samples from G-Tunnel rubble were compressed to expel gas and water samples for analyses. The gas samples were analyzed for sulfur hexafluoride, carbon dioxide, and methane. Preliminary results indicate that blast components were present in some samples. About 100 samples have been sent to a laboratory for analyses. Rock samples from G-Tunnel were also selected and sent for cation exchange and mineralogic analyses. A report on the blasting work at G-Tunnel is being prepared by the USBR.

Samples of gas and water vapor were collected from cores of short boreholes cored and drilled into G-Tunnel rock immediately after the completion of blasting. Samples were analyzed for concentrations of carbon dioxide, methane, nitrogen, oxygen, argon, and ethane.

Prototype testing of the dry coring of rubble continued. The nonwelded rubble sample coring was completed. About 60 core samples were cored by the USGS/USBR in Denver and about eight core samples were cored by Holmes and Narver at the materials testing lab at the NTS. The welded rubble sample coring has begun at both Denver and at the NTS. About 15 core samples have been cored from welded rubble by personnel at each location. The temperature of the bit during coring was as high as 137°F. The high temperature was associated with fast penetration rates and low gas circulation rate (nitrogen or air). Another method of core cutting using diamond-impregnated fine wire is under evaluation.

Prototype uniaxial-compression extraction of pore water and gas from G-Tunnel cores continued. Approximately 35 cores were prepared and compressed, and 10 rock and 100 water samples were sent for analyses. Six

densely-welded tuff core samples were artificially saturated with a synthetic UZ water under a vacuum. These cores have been compressed and the water and gas is being analyzed to determine the effects of compression on water chemistry in welded rock. These artificial conditions were necessary because the present compression methods could not remove water from cores with less than 5% moisture content and all available welded core contained less than 5%. A new "second generation" uniaxial cell was fabricated. This new cell should be able to obtain water from cores down to about 2 to 3% moisture content.

A paper on pore water extraction from unsaturated tuff by compression methods is in the final stages of editing for publication as a USGS Water Resources Investigation Report; the paper is also in the review process. Papers were prepared for presentation at the 1991 Spring American Nuclear Society (ANS) meeting in Las Vegas and for inclusion in a USGS Bulletin.

2.2.1.12 Study 8.3.1.2.2.8 - Fluid Flow in Unsaturated, Fractured Rock

Study Plan 8.3.1.2.2.8 was technically reviewed and revised by the USGS and submitted to the Project Office on September 7, 1990.

Activity 8.3.1.2.2.8.1 - Development of Conceptual and Numerical Models of Fluid Flow in Unsaturated, Fractured Rock. Input was provided to the Calico Hills Risk/Benefit Task Force, for ESF construction methods and ESF design alternatives. Presentations on ESF prototype tests, process modeling, and site-scale modeling were made for the UZ Peer Review Team on June 4-6, and at the NRC/DOE technical exchange on September 26 and 27.

"Prototype Testing of Instruments for Monitoring Water and Tracer Movement in the Proposed Exploratory Shaft Percolation Test at Yucca Mountain, Nevada" (Marvil et al.), "Study of Fractal Aperture Distribution and Flow in Fractures" (Kumar et al.), and "Combined Analytical/Numerical Approaches to Solving Fluid Flow Problems in the Unsaturated Zone at Yucca Mountain" (Zimmerman et al.) have been submitted for the CASY bulletin. The Zimmerman et al. and Kumar et al. papers were presented at the International Topical Meeting on High Level Radioactive Waste Management. A paper titled "Numerical Simulations Performed in Support of the Prototype and Exploratory Shaft Percolation Tests" (Kwicklis), intended as a Water Resources Investigation Report, is in editorial review. Papers submitted to Water Resources Research were "The Effect of Air Viscosity in One-Dimensional Infiltration in Unsaturated Porous Media" (Chen et al.), "Absorption of Water into Porous Blocks of Various Shapes and Sizes" (Zimmerman et al.), "Comment on Exact Integral Solutions for Two-Phase Flow" (Chen et al.), and "Permeability of a Fracture with Cylindrical Asperities" (Kumar et al.). "The Effect of Applied Pressure on One-Dimensional Infiltration in Unsaturated Porous Media" (Chen et al.) was accepted for the 1990 Society of Petroleum Engineers meeting. "Integral Method Solutions to Flow Problems in Unsaturated Porous Media" (Zimmerman and Bodvarsson) was accepted for a Society of Industrial Applied Mathematics Conference on Mathematical and Computational Issues in Geophysical Fluid and Solid Mechanics. "Permeability of a Fracture with Cylindrical Asperities" (Kumar et al.) was submitted to Journal of Fluid Dynamics Research. "Permeability of Rough-Walled Fractures" (Zimmerman et al.) was prepared and a poster session "Fluid Flow in Rough-Walled Fractures" (Zimmerman et al.) was presented at CASY Symposium on September 13-14, 1990.

An abstract of a presentation titled "Investigation of Fluid Flow in Unsaturated Fractured Rocks" was published in the Proceedings of the AIH Spring Meeting (Bodvarsson et al., 1990).

Analysis of pneumatic pressure data from G-Tunnel show pressure transients in fractured rock may be used to derive estimates of permeability at distance from the drift wall where porous media behavior is observed. A stochastic fracture model was used to discretize the plane of a variable aperture fracture into spatially correlated zones of constant aperture. Hysteretic curves may be developed using this model. Cumulative imbibition versus time data were successfully simulated. Feasibility of a laboratory test to measure relative magnitude of downdip flow at a contact was modeled. A curve-matching program, SFIT, was used to predict van Genuchten parameters from imbibition data. There were too many unknown parameter values for the code to estimate simultaneously. Sensitivity analyses were run to optimize tracer recovery following dry drilling with tracer-tagged air. Scoping simulations to predict liquid saturation and liquid relative permeability of a variable aperture fracture as a function of matric potential under wetting conditions produced fracture characteristic curves differing significantly from those observed for porous media. Simulations performed to generate an equivalent continuum hydraulic conductivity-matric potential relation for a simple fracture network show displacement from the relation for individual fractures. Codes constructed for relative permeability and saturation versus matric potential relations for wetting and drying conditions will be incorporated in this model.

2.2.1.13 Study 8.3.1.2.2.9 - Site Unsaturated-Zone Modeling and Synthesis

Internal USGS technical review of Study Plan 8.3.1.2.2.9 was completed. The study plan is being revised in response to the review prior to submittal to the Project Office.

Activity 8.3.1.2.2.9.1 - Conceptualization of the Unsaturated-Zone Hydrogeologic System. Refinement of existing and alternative unsaturated-zone numerical flow models for the Yucca Mountain hydrogeologic system using available field and laboratory data is continuing at Lawrence Berkeley Laboratory (LBL). Emphasis continues to be focused on the large-scale effects of moisture flow in the UZ. Site-scale numerical-model development continued at LBL with techniques to decouple the governing equations of the numerical code TOUGH. This decoupling of parameters will allow for quicker computation in solving hydrological problems. The interpretive results of these functions have resulted in the following: a short LBL technical report describing the decoupling of TOUGH is approximately 50 percent complete; LBL investigators reviewed a USGS/USBR draft position paper on subsurface fracture data needs and the ability to meet those needs using different excavation methods, and submitted their review comments to the USGS; a summary of LBL's cooperative work with the USGS was presented at the Unsaturated-Zone Peer Review Team Meeting, held in Las Vegas; an LBL paper entitled "Permeability of a Fracture with Cylindrical Asperities" (Kumar et al.) was reviewed by the Journal of Fluid Dynamics Research and is being revised according to reviewers' comments; and LBL investigators met in Berkeley with USGS investigators late in the fiscal year to discuss the work scope for FY 91.

A presentation entitled "Site-Scale Flow Modeling and Data Requirements" (Hoxie and Bodvarsson) was made during September by LBL and USGS investigators at the DOE-NRC Technical Exchange on UZ Hydrology and Geochemistry Testing. In preparation for this DOE-NRC Technical Exchange, LBL and USGS investigators attended several planning/scoping meetings in Denver. Science Applications International Corporation (SAIC)-Golden personnel visited LBL and inventoried all pre-1988 LBL documents containing Yucca Mountain data, to determine if they should be transmitted to the Central Records Facility in Las Vegas. USGS investigators served on committees and attended many meetings to assist in prioritizing functions within the ESF Alternate Studies testing panel, ESF Alternate Studies post-closure health and safety panel, CHRBA, and SBTP reviews and schedule modifications.

2.2.1.14 Study 8.3.1.2.3.1 - Characterization of the Site Saturated-Zone Ground-Water Flow System

DOE comment resolution workshops for Study Plan 8.3.1.2.3.1 (Activities 1-6) were completed, and the plan was resubmitted to the Project Office on May 18, 1990. The portion of the study plan covering Activities 1-6 is currently in DOE audit review.

The portion of the study plan for Activity 7 was submitted to the NRC on April 10.

Activity 8.3.1.2.3.1.2 - Site Potentiometric-Level. Monitoring of water levels in the saturated zone at Yucca Mountain continued. Monthly water-level measurements were made in 12 wells in the periodic network. Hourly water-level data were collected from 22 zones in 15 wells in the continuous water-level network. Approximately 50 transducer calibrations were performed on the continuous network and approximately 10 transducers were replaced. Water levels remained stable during the April-September 1990, period and the rate of instrument failure remained at an acceptable level.

Four separate wide-spread apparent water-level anomalies occurred during the period. Whether these anomalies represent instrument malfunction or real water-level changes remains unknown. The anomalies, present in from 7 to 12 zones, lasted from a few hours up to several days. The anomalies occurred during periods of unsettled weather with drops in barometric pressure, rain, and lightning strikes. Satellite data collection platforms that send data from two wells directly to a Prime computer in Denver were used to monitor the apparent anomalies. The data, which were transmitted every four hours, were routinely monitored daily and were monitored after every transmission when conditions were favorable for an anomaly. No manual measurements were made during an anomaly to determine if it was real, but on two separate occasions measurements were made within two hours of the anomaly.

The 1989 report on periodic water-level measurements has been through USGS colleague review and has been revised. The report on the continuous water-level network for 1985-88 is being revised following USGS review and work on the 1989 continuous water-level report was begun. An abstract of a presentation titled "Water-Level Monitoring to Characterize the Ground-Water Flow System at Yucca Mountain" was published in the Proceedings of the AIH Spring Meeting (Luckey, 1990).

In June, access tubing to measure the water level was removed from well UE-25p#1, and water samples were taken from near the bottom of the well with a thief sampler. The samples were in support of planning for Activity 8.3.1.5.2.1.5--studies of calcite and opaline-silica vein deposits. The tubing was replaced and the well was returned to the continuous water-level network. As part of the same work, an obstruction was pushed down in the access tube to the lower zone of well USW H-5, so water levels could be monitored. An unsuccessful attempt was made to do the same remedial work on well USW H-3.

A proposal was finalized for additional wells to determine the configuration of the potentiometric surface north of Yucca Mountain. These wells are needed to define boundary conditions for both site and subregional flow models. A site on the south end of Yucca Mountain was visited to see if a well could be drilled there. An NRC comment on the SCP suggested that a well in this area was needed. A decision regarding the need for an additional well at this site will be made later.

Activity 8.3.1.2.3.1.3 - Analysis of Single- and Multiple-Well Hydraulic Stress Tests. Preparation of a report describing the results of intraborehole flow and hydraulic stress tests has been initiated. The analysis of several different sets of temperature logs, which help to qualitatively identify discrete flow zones, has been completed. One additional set of temperature logs has been collected in preparation for the removal of existing tubing and packers from the three UE25-c holes. This last set of temperature logs will be used for direct comparison with logs that will be collected after the packers have been removed.

Previously completed pumping and injection tests are now being reanalyzed using a modular well test analysis program that allows rapid use of different analytical solutions. This will help determine which solutions best fit the data and thus help identify the type of flow (i.e., radial, spherical, discrete fracture, dual porosity, etc.) that will be encountered during future testing. The modular well test analysis program has been and continues to be debugged and corrected as problems are discovered.

Hydraulic fluid pressure responses to earth tides, barometric pressure changes, earthquakes, and underground nuclear explosions (UNEs) continued to be monitored and the monitoring method was continually refined. In addition, an analytical method for determining pneumatic diffusivity from annular-space gas-pressure measurements was developed and applied to data collected at UE-25c#1. So far, this method has provided results similar to those obtained from earth tide analysis. Additional data collection is needed to further evaluate this method, but it may provide supporting data to verify the results of earth tide analysis and help in developing single well testing procedures. Gas-pressure measurements from three shallow neutron holes are currently being collected to help in refining this technique.

A report "Strain-Related Water-Level and Fluid-Pressure Responses in Wells, Yucca Mountain" (Galloway et al.) was written and submitted for publication in a USGS Bulletin containing papers from the USGS-Yucca Mountain Project symposium held last year in Death Valley.

A technical poster "Hydrologic Analysis of Periodically Varying Strain and Pressure Waves: Atmospheric, Earth Tide, and Seismic" (Galloway et al.) was presented at the September USGS-Yucca Mountain Project symposium on the effect of fractures on the hydrology of Yucca Mountain.

Activity 8.3.1.2.3.1.4 - Multiple-Well Interference Testing. The multiple-zone hydraulic and tracer testing packer system was continually evaluated and redesigned. Several difficult technical problems were encountered and overcome. An example of the type of difficulty encountered was deciding what type of transducer will successfully measure the large range of fluid pressure changes expected in the pumped well and also be capable of measuring small changes in the monitoring wells. Differential transducers were selected because of their ability to measure both of these situations with the required accuracy, but differential transducers for use at depths of as much as 1600 feet are not commonly available. Meetings with representatives of the manufacturer of the transducers most commonly used at the test site resulted in their agreeing to modify one of their differential transducers for underwater use. The reference line for these transducers will be filled with water as the packer tool is lowered into the borehole. When the packer string is lowered to the required depth, a solenoid valve at the bottom of the reference line will be closed to seal off the reference line. The measurements will then be measured by the differential transducers using the original water table as a reference.

Researchers at LBL completed a detailed comparison of commercially-available resonant piezoelectric seismic sources and assessed their suitability for use in the cross-hole vertical profiling at the C-hole complex. One source was selected based on the fact that it is about five times more powerful than the other sources available. Purchase of one of these sources has been initiated.

Activity 8.3.1.2.3.1.5 - Testing of the C-Hole Sites with Conservative Tracers. Laboratory testing of various tracers, primarily pyridine derivatives, was begun by hydrochemists at the University of Nevada/Las Vegas (UNLV). These tests involve both ease of detection at low concentrations and sorption studies in columns packed with Bullfrog tuff thought to be representative of that present at the C-hole complex. Core from the planned fourth borehole at the C-hole site will be used to verify the representativeness of the materials used in the column studies.

Work was begun to run the preliminary simulations of the tracer tests using FEHMS (developed at LANL) and TRINET (developed at LBL). These preliminary simulations are designed to provide UNLV hydrochemists with flow volumes and rates needed to select initial concentrations of tracers to be injected.

Design of the tracer injection system to be coupled with the multiple-zone packer system was completed by USGS and USBR.

Activity 8.3.1.2.3.1.7 - Testing of the C-Hole Sites with Reactive Tracers. A conceptual model for transport in the saturated zone was developed. The model incorporated two key phenomena--diffusion of radionuclides into the rock matrix and sorption on the rock surface. These two mechanisms resulted in much longer radionuclide travel times than was

predicted with models that did not account for these phenomena. Planning for the C-holes reactive tracer field tests focused on demonstrating matrix diffusion and sorption in the field.

In modeling, extensive documentation of the finite-element heat and mass transfer code FEHMN was completed. When the Software Quality Assurance Plan (SQAP) is approved, all LANL Project codes will use a standardized input/output (I/O) software package to handle I/O. The feasibility of using the software package, called netCDF, was proven by modifying I/O of the code FRACNET. The netCDF package also provided a superior system for handling I/O from FORTRAN computer codes.

The detailed technical procedure for the ion chromatograph was completed after extensive testing of the equipment.

Activity 8.3.1.2.3.1.8 - Well Testing with Reactive Tracers throughout the Site. No progress during the reporting period.

2.2.1.15 Study 8.3.1.2.3.2 - Characterization of the Saturated-Zone Hydrochemistry

Draft Study Plan 8.3.1.2.3.2, transmitted to the Project Office for initial review on March 28, 1990, is still in review at DOE.

Activity 8.3.1.2.3.2.1 - Assessment of Saturated-Zone Hydrochemical Availability and Needs. Efforts continued to identify and obtain extant and new ground-water chemical data for the NTS and vicinity. EPA personnel in Las Vegas were contacted in order to obtain copies of their annual reports of monitoring activities at and in the vicinity of the NTS. Wireline samples were collected and composited from well UE-25p#1 (completed in Paleozoic carbonates beneath the eastern margin of Yucca Mountain) to provide estimates of the values of ^{87}Strontium/^{86}Strontium and ^{234}Uranium/^{238}Uranium ratios, noble-gas concentrations, and ^{36}Chlorine in ground waters beneath the tuff section. These data will provide insight as to the need for more rigorous sampling at this site and for additional data relevant to the Paleozoic units. A preliminary coordination meeting was held with DOE/Environmental Restoration Waste Management (ERWM), DRI, and contractor personnel (at the DOE/Swedish Nuclear Fuel Supply Company (SKB) technical exchange meeting) to discuss the integration of DOE's ERWM-DRI and Project efforts relative to ground-water characterization.

Study needs relevant to downhole pressure transducers were presented to representatives of Druck, Inc. Manufacture recommendations and suggestions were noted. Follow-up on the meeting by Druck staff indicated that they (Druck) can supply appropriate equipment to be used in the course of sampling WT boreholes at and in the vicinity of Yucca Mountain. The transducers will be part of the instrument/equipment package assembled for sample and field-data collection at the WT holes.

Formulation of requisite specifications for a mobile field laboratory to support ground-water sample and field-data collection was begun. Discussions with several investigators (USGS, SKB, Western Analytical Corporation) and mobile laboratory manufacturers in California, Colorado, and Iowa provided a

starting point from which to plan. An ion chromatograph system and supporting microcomputer hardware and software, which will ultimately be installed in the mobile laboratory, were obtained and installed in a laboratory in Denver. Familiarization testing and methods development have been started and are anticipated to proceed for at least six months.

An article entitled "Sampling 'Shallow' Ground Water at Yucca Mountain, Nevada" (Steinkampf and Matuska) was submitted to Ground-Water Monitoring Review for publication.

2.2.1.16 Study 8.3.1.2.3.3 - Saturated-Zone Hydrologic System Synthesis and Modeling

Study Plan 8.3.1.2.3.3 was revised in response to USGS technical review and was transmitted to the Project Office on September 4, 1990.

Activity 8.3.1.2.3.3.1 - Conceptualization of Saturated-Zone Flow Models Within the Boundaries of the Accessible Environment. Coordination of saturated-zone modeling efforts was a priority during this reporting period. Two informal modeling meetings were held with saturated-zone modelers to discuss areas of common interest, cooperative efforts and data needs for ground-water modeling. The three-dimensional Geographic Information System (GIS), being developed by the Quaternary Regional Hydrology Study, Study Plan 8.3.1.5.2.1, was discussed as a possible location for data collected at Yucca Mountain. The GIS would be useful for aiding in data synthesis and management, for formatting data input to ground-water flow models, and for the testing of hydrologic and geologic hypotheses. To aid in coordination of models at different scales and for different purposes, Study Plan 8.3.1.2.1.4, Regional Hydrologic System Synthesis and Modeling, was reviewed by a USGS ground-water modeler in the Site Saturated-Zone project. Water-level data synthesis, on the scale of Yucca Mountain, was initiated. Work began on a revised preliminary potentiometric map using the 1988 average water-level data. A field trip description was written for the GSA fall 1991 field trip section, entitled "A Hydrogeologic Overview of the Regional Ground-Water Flow System in Relation to Yucca Mountain, Nevada" (Chornack et al.). The computer code FMMG developed by LBL scientists was revised so it could be installed on the USGS Prime computer.

Activity 8.3.1.2.3.3.2 - Development of Fracture-Network Model. Scientists at LBL transferred their TRINET model for fracture-network flow and transport to a CRAY-2 computer. The LANL computer model FEHMS was installed by USGS scientists on a SUN workstation. Preliminary work was conducted to simulate coupled hydraulic and stress responses at the UE-25c holes. Past UE-25c-hole hydraulic-test results were matched successfully with fractal geometry using a numerical flow simulator model. A presentation was made at the fall USGS-Project technical meeting on modeling flow and transport in fracture networks by LBL. A study to examine how different sets of synthetic fracture distributions compare to representation in boreholes was initiated.

2.2.2 Geochemistry (SCP Section 8.3.1.3)

2.2.2.1 Study 8.3.1.3.1.1 - Ground Water-Chemistry Model

The study plan was revised to incorporate technical review comments, and the reviewers determined that the revisions do not require a second technical review. The study plan was then submitted for LANL QP-3.2 technical review.

Ground-water chemistry data from efforts at LANL (e.g., Kerrisk and Ogard, 1984) were submitted to the Reference Information Base.

2.2.2.2 Study 8.3.1.3.2.1 - Mineralogy, Petrology, and Chemistry of Transport Pathways

The study plan was approved by the NRC on September 4.

Activity 8.3.1.3.2.1.1 - Petrologic Stratigraphy of the Topopah Spring Member. Statistical analysis of mineralogic and chemical data for Topopah Spring samples from Solitario Canyon--a prototype test for use in developing sampling procedures for the ESF--is on hold because of the LANL stop work order on computer software. Completion of the statistical analysis and publication of the results will resume after the LANL SQAP is approved and the LANL stop work order is lifted.

Activity 8.3.1.3.2.1.2 - Mineral Distributions between the Host Rock and the Accessible Environment. Work continued on evaluating possible sites at Yucca Mountain for an adit in which field experiments may be performed. A total of 92 samples collected by LANL and SNL were analyzed for mineralogic, chemical, and petrographic characteristics. Collection of x-ray diffraction (XRD) data was completed for these samples, but reduction of the data cannot take place until the LANL software stop work order is lifted. Chemical and petrographic studies continued.

In trace mineral studies, the International Scientific Instruments SEM was used to examine oxide microphenocrysts and associated alteration products of the devitrified Topopah Spring Member.

Activity 8.3.1.3.2.1.3 - Fracture Mineralogy. Work continued on the identification of minerals from fractures in the Topopah Spring Member from drillholes USW G-1, G-2, and GU-3.

A talk entitled "Distribution of Fracture-Lining Minerals at Yucca Mountain" was presented by B. Carlos at the CASY Symposium on Fractures, Hydrology, and Yucca Mountain held in Denver on September 13-14. A report entitled "Manganese-Oxide Minerals in Fractures of the Crater Flat Tuff in Drill Core USW G-4, Yucca Mountain, Nevada" was published (Carlos et al., 1990).

2.2.2.3 Study 8.3.1.3.2.2 - History of Mineralogic and Geochemical Alteration at Yucca Mountain

The study plan revision, based on resolved DOE/HQ comments, was completed.

A QA grading package was prepared to facilitate interactive work with the USGS. The LANL software stop work order continued to prevent the use of the electron microprobe and other analytical capabilities for ongoing site characterization activities.

A paper entitled "Thermal Stability of Zeolitic Tuff from Yucca Mountain, Nevada" (Bish, 1990), was presented at the 1990 International Topical Meeting on High Level Radioactive Waste Management held in Las Vegas, Nevada, and published in the conference proceedings.

Activity 8.3.1.3.2.2.1 - History of Mineralogic and Geochemical Alteration at Yucca Mountain. Preliminary prototype potassium/argon (K/Ar) dating of zeolite samples from Yucca Mountain was completed. An abstract on the interpretation of paleohydrologic and paleothermal conditions in a volcanic sequence using mineralogical and K/Ar dating information was accepted for presentation at the GSA annual meeting.

Activity 8.3.1.3.2.2.2 - Smectite, Zeolite, Manganese Minerals, Glass Dehydration and Transformation. Long-term heating studies of zeolite and clay samples continued, with periodic XRD monitoring of crystal lattice structural changes. Long-term vitrophyre dehydration studies also continued.

2.2.2.4 Study 8.3.1.3.3.1 - Natural Analog of Hydrothermal Systems in Tuff

This study was not active during the reporting period.

2.2.2.5 Study 8.3.1.3.3.2 - Kinetics and Thermodynamics of Mineral Evolution

Activity 8.3.1.3.3.2.1 - Kinetic Studies of Zeolite and Related Framework Silicates. No progress during the reporting period.

Activity 8.3.1.3.3.2.2 - Determination of End-Number Free Energies for Clinoptilolite, Heulandite, Albite, and Analcime. Analysis of scoping experiments on the kinetics of silica polymorph transitions was initiated.

2.2.2.6 Study 8.3.1.3.3.3 - Conceptual Model of Mineral Evolution

Examination began of the possible effects of cation exchange between downward flowing water and the upper clinoptilolite zones and possible constraints on matrix water flux.

2.2.2.7 Study 8.3.1.3.4.1 - Batch Sorption Studies

Study plan revisions and comment resolution were completed.

A talk on the radionuclide sorption data base--experiments and integration of relevant sorption models--was presented to the Radionuclide Adsorption Workshop in Los Alamos on September 11-12.

Activity 8.3.1.3.4.1.1 - Batch Sorption Measurements as a Function of Solid Phase Composition. Experiments to determine the sorption of neptunium (Np) on pure mineral phases were initiated and continued during the reporting period. The computer code EQ3/6 has been used to help determine the possible species of Np in solution to unravel the mechanisms of actinide sorption.

Experiments with technetium (Tc) sorption onto pure mineral phases in J-13 well water at pH=7.0 were completed. Data reduction is continuing for these experiments.

Activity 8.3.1.3.4.1.2 - Sorption as a Function of Sorbing Element Concentrations (Isotherms). This activity was inactive during the reporting period.

Activity 8.3.1.3.4.1.3 - Sorption as a Function of Ground-Water Composition. The Stanford group completed a set of experiments to determine the sorption of neptunium on hematite as a function of pH and the CO_2 content of the atmosphere above the experiment.

Activity 8.3.1.3.4.1.4 - Sorption on Particulates and Colloids. This activity was inactive during the reporting period.

Activity 8.3.1.3.4.1.5 - Statistical Analysis of Sorption Data. In preparation for the Radionuclide Adsorption Workshop in Los Alamos on September 11-12, an evaluation was conducted of the actinide sorption data base in terms of water chemistry parameters such as pH. In addition, during a literature analysis for data on adsorption of technetium, iodine, and carbon (C), important data were obtained on the adsorption of C as carbonate and bicarbonate ions.

2.2.2.8 Study 8.3.1.3.4.2 - Biological Sorption and Transport

The study plan received Project Office and DOE/HQ review comments, and a comment resolution meeting was held June 21-22, 1990. Review comments were incorporated.

Detailed technical procedure TWS-LS2-DP-403, Rev. 0, was prepared and submitted for review.

Complexation experiments between chelating agents and plutonium [^{239}Pu(IV)] were performed.

Siderophore purification was accomplished by using semipreparative microbondapack CN columns for high-pressure liquid chromatograph techniques.

2.2.2.9 Study 8.3.1.3.4.3 - Development of Sorption Models

No progress during the reporting period.

2.2.2.10 Study 8.3.1.3.5.1 - Dissolved Species Concentration Limits

The study plan underwent internal technical and programmatic review and was revised in response to LANL review comments. The revision was submitted to the Project Office on September 17.

Activity 8.3.1.3.5.1.1 - Solubility Measurements. A number of pure oxidation state solutions were prepared for the Sorption and Biological Sorption tasks.

Solubility measurements for neptunium, plutonium, and americium in J-13 well water at 25°, 60°, and 90°C and at pH values of 6, 7, and 8.5 were completed. Solubility experiments also continued on these key actinides in UE-25p#1 well waters under the same conditions as above.

Activity 8.3.1.3.5.1.2 - Speciation Measurements. Radionuclide speciation studies continued by developing and testing alternative methods of waveform acquisition and analysis in photoacoustic spectroscopy. A new analog waveform rectifier was assembled and integrated into the system. Performance was evaluated in comparison to simple boxcar integration schemes and LANL's novel full waveform digital analysis scheme. Substantial work was devoted to understanding the relationship between the raw photoacoustic waveform and the encryption of analytically useful information.

New work was undertaken to implement thermal lensing as an alternative method (to photoacoustic pressure sensing) for detection in photothermal spectroscopy. The implementation is complete and operational, and the system was optimized for improved sensitivity.

Work continued on the modification, streamlining, and documentation of the computer code used for photothermal spectroscopy instrumentation control and data acquisition. Staff worked toward the compliance guidelines in the SQAP. When final versions of these procedures are issued, the LANL stop work order can be lifted and collection of radionuclide speciation data using photothermal spectroscopy can commence.

A new experimental effort was initiated using nuclear magnetic resonance spectroscopy (^{1}H, ^{13}C, and ^{18}O) as a very powerful speciation tool. Preliminary data were collected for the uranyl carbonate monomertrimer equilibrium system. These results were very encouraging and have led staff to begin planning to extend these studies to include plutonium and neptunium in the near future. Radionuclide speciation information obtained utilizing this tool will provide a basis for identifying speciation signatures obtained using photoacoustic and photothermal spectroscopic techniques.

Significant progress was made in four areas of new model complex speciation studies: (1) The acquisition and assembly of the inert atmosphere facilities for the synthesis of these model complexes continued. The major components are on-site, and installation is planned; (2) the synthesis of a

multitude of Th(IV) model complexes has been successfully carried out, and many of these complexes have been characterized by XRD; (3) spectroscopic characterization of a number of U(IV) and Th(IV) model complexes using UV-visible-near infrared electronic absorption, emission, and Raman vibrational spectroscopies has been conducted; and (4) new experimental approaches to controlling and understanding actinide hydrolysis were initiated. Data have been collected for the controlled hydrolysis of U(IV) as UCl_4 in tetrahydrofuran.

A paper was presented at the 200th National Meeting of the American Chemical Society (Morris et al., 1990). This paper described the instrumentation development and optimization for the photothermal spectroscopy capability for speciation studies relevant to this activity. Results for Nd^{3+} and Pu^{4+} were presented to demonstrate the performance of the system.

Activity 8.3.1.3.5.1.3 - Solubility Modeling. This activity was inactive during the reporting period.

2.2.2.11 Study 8.3.1.3.5.2 - Colloid Behavior

The study plan underwent internal technical and programmatic review and was revised in response to review comments. The revision was submitted to the Project Office on September 17.

Activity 8.3.1.3.5.2.1 - Colloid Formation Characterization and Stability. Experimental design and instrumentation acquisition were undertaken to determine several important physicochemical properties of Pu(IV) colloid. These include molecular weight determinations using colligative properties (freezing-point depression and osmotic pressure) and determinations of water content using thermal gravimetric analysis.

A number of Pu colloid samples were prepared and are aging in preparation for the expected x-ray absorption spectroscopy (EXAS) experiments. Cell design and construction neared completion for the EXAS studies. These experiments should provide the definitive molecular structural information for Pu(IV) colloid.

Activity 8.3.1.3.5.2.2 - Colloid Modeling. This activity was inactive for the reporting period.

2.2.2.12 Study 8.3.1.3.6.1 - Dynamic Transport Column Experiments

Project Office and DOE/HQ review comments on the study plan were addressed, and a comment resolution meeting was held on August 29 that resolved all comments.

A talk on radionuclide migration studies for validating sorption data was presented at the Radionuclide Adsorption Workshop in Los Alamos on September 11-12.

Activity 8.3.1.3.6.1.1 - Crushed Tuff Column Experiments. The transport behavior of simple cations and actinide species was studied utilizing column

experiments; the solid phases studied were zeolite, clay, calcite, and metal oxides and oxyhydroxides. The objective of this research was to study the migration of radionuclides as a function of mineralogy. The results will aid in the elucidation of the dominant chemical mechanisms of radionuclide migration, the prediction of radionuclide transport in conditions similar to those expected at the candidate repository site at Yucca Mountain, and the identification of materials that can act as natural geological barriers or be utilized as strong sorbers for specific radionuclides in engineered barriers.

Activity 8.3.1.3.6.1.2 - Mass Transfer Kinetics. No progress during the reporting period.

Activity 8.3.1.3.6.1.3 - Unsaturated Tuff Columns. Previous experiments on the migration behavior of simple cations through solid rock columns indicated that time-dependent dispersion was necessary to interpret elution data and that hydraulic and mineralogic heterogeneities seemed to be dominant factors in the observed migration behavior. Therefore, an x-ray diffractometer was upgraded to allow determination of potential mineralogic spatial variations throughout the solid rock columns exhibiting time-dependent dispersion, and analysis of the mineralogy throughout solid rock columns was initiated.

A literature search was completed to identify transport work performed under unsaturated conditions. Most of the work in this area has been performed using unconsolidated materials. The work of J. Conca, Washington State University, which deals with the development of a new flow apparatus for transport studies, looks promising for migration studies under unsaturated conditions using consolidated materials, such as intact tuff. Conca's apparatus consists of a modified ultracentrifuge with an ultraflow constant-rate flow pump, which provides water to the material's surface at a constant flow rate down to 0.1 ml/hr during accelerations up to 20,000 g. Hydraulic steady state is reached relatively rapidly. This type of system could be utilized for the planned unsaturated transport experiments.

Activity 8.3.1.3.6.1.4 - Fractured Tuff Column Studies. No progress during the reporting period.

Activity 8.3.1.3.6.1.5 - Filtration. Efforts continued to characterize synthetic and natural colloids for studies to determine the ability of Yucca Mountain tuffs to act as a filter for colloidal particles. The auto-correlation photon spectrometer (APS) was upgraded to determine the size, as well as concentration, of colloidal particles in suspension. Previously, the APS system was capable of determining particle size in a colloidal suspension and the amount of light scattered by particles of each size. The equipment upgrade, in combination with software that will be developed when the LANL software stop work order is lifted, will determine the concentration of particles of each size. This effort will require incorporating Mie Theory into the analysis. The theoretical work preceding code development has been effected during this period. To test the performance of the APS system, particles of known sizes were acquired from the NIST.

2.2.2.13 Study 8.3.1.3.6.2 - Diffusion

The Project Office and DOE/HQ review comments on the study plan were addressed, and a comment resolution meeting was held on August 30 that resolved all comments.

Activity 8.3.1.3.6.2.1 - Uptake of Radionuclides on Rock Beakers in a Saturated System. No progress during the reporting period.

Activity 8.3.1.3.6.2.2 - Diffusion through a Saturated Tuff Slab. Solutions made with water from NTS well J-13 and radionuclides of interest were placed in contact with containers made of intact tuff. The uptake of radionuclides (technetium, strontium, cesium, barium, neptunium, and americium) in the solutions was monitored as a function of time. The data collected will be analyzed using the TRACRN code after the LANL software stop work order is lifted. These experiments will allow the study of diffusion utilizing nonsorbing tracers as well as the kinetics of sorption using sorbing cations and actinides.

Activity 8.3.1.3.6.2.3 - Diffusion in an Unsaturated Tuff Block. To study diffusion in unsaturated conditions, staff completed the equilibration of water from NTS well J-13 in unsaturated blocks made of intact tuff with Topopah Spring Member outcropping samples. The blocks, which are 60% saturated with J-13 water, are now ready for injection of nonsorbing and sorbing tracers. However, the tracers will not be injected into the unsaturated blocks until modeling of the potential diffusion process is completed, which will be effected with TRACRN after the LANL stop work order is lifted.

2.2.2.14 Study 8.3.1.3.7.1 - Retardation Sensitivity Analysis

A study plan comment resolution meeting was held July 31, 1990, which resolved all comments.

A talk on the radionuclide transport and retardation model was presented to the Radionuclide Adsorption Workshop in Los Alamos on September 11-12, 1990. Three papers were published in the proceedings for the first annual International Topical Meeting on High Level Radioactive Waste Management: "Simulation of Radionuclide Retardation at Yucca Mountain Using a Stochastic Mineralogical/Geochemical Model" (Birdsell et al.); "Simulation of Heat Transfer in the Unsaturated Zone" (Zyvoloski); and "Modeling of Coupled Heat-Mass-Stress Effects in Geologic Media" (Kelkar and Zyvoloski).

Staff assisted in drafting and reviewing the Los Alamos SQAP.

Activity 8.3.1.3.7.1.1 - Analysis of Physical/Chemical Processes Affecting Transport. All progress under this activity was impacted by LANL stop work order SWO-LANL-01, and technical progress was restricted to supporting Performance Assessment Calculational Exercise (PACE) activities. Calculations were performed to examine the far-field transport to the water table for four radionuclides--^{129}I, ^{99}Tc, ^{137}Cs and ^{237}Np. These calculations were grouped as nominal case, disturbed cases, and sensitivity analyses. LANL PACE contributions were to provide retardation information and to perform

UZ calculations in two and three dimensions, using as complete an input data set as currently available.

The nominal case was a transport calculation at a 0.01-mm/yr average percolation rate from the repository to the water table. The PACE group selected this flow rate as the best one-dimensional fit to existing moisture content data.

The disturbed case calculations were run for the same radionuclides at 0.1- and 0.5-mm/yr average percolation rates. Comparison of the LANL three-dimensional simulation and two- and one-dimensional simulations by other participants showed sensitivity to dimensional analysis (i.e., a three-dimensional analysis is needed).

An exemption to the LANL stop work order was granted to complete preliminary documentation of the colloid transport code, CTCN. A draft users manual for the code was produced; however, the document will not be published until the SQAP requirements are finalized.

Activity 8.3.1.3.7.1.2 - Geomechanical/Geophysical Model of Yucca Mountain and Integrated Geochemical Transport Calculations. All work in this study was restricted by LANL stop work order SWO-LANL-01.

Activity 8.3.1.3.7.1.3 - Transport Models and Related Support. An exception to LANL stop work order SWO-LANL-01 was granted to complete FY 89 milestones that included documentation for TRACRN, which will be published next reporting period.

2.2.2.15 Study 8.3.1.3.7.2 - Demonstration of Applicability of Laboratory Data to Repository Transport Calculations

The development of study plans for large-scale field tests, intermediate-scale field tests (caissons), and natural analog studies was initiated.

Natural Analog staff attended a meeting in Pinawa, Manitoba, on the Cigar Lake Analog study. LANL is a participant with the Atomic Energy of Canada Limited/DOE program.

2.2.2.16 Study 8.3.1.3.8.1 - Gaseous Radionuclide Transport Calculations and Measurements

This study was inactive during the reporting period.

2.2.3 Rock Characteristics (SCP Section 8.3.1.4)

2.2.3.1 Activity 8.3.1.4.1.1 - Development of an Integrated Drilling Program

All related work is described with prototype drilling description (see Study 8.3.1.2.2.3).

2.2.3.2 Activity 8.3.1.4.1.2 - Integration of Geophysical Activities

Progress is reported under the activities in which this work is being performed. The major product to date for this activity is the "Geophysics White Paper" (Oliver et al., 1990), which formally presents the data, major results, and plans for geophysical activities for the Yucca Mountain Project. The NRC concern with the adequacy and overall integration of geophysical activities in the SCP/CD was the impetus for DOE to prepare this "White Paper."

2.2.3.3 Study 8.3.1.4.2.1 - Characterization of the Vertical and Lateral Distribution of Stratigraphic Units within the Site Area

Study Plan 8.3.1.4.2.1 was transmitted to the Project Office on April 9, 1990. The Project Office screening review was completed on May 10, 1990.

Activity 8.3.1.4.2.1.1 - Surface and Subsurface Stratigraphic Studies of the Host Rock and Surrounding Units. USGS staff analyzed selected samples of the Topopah Spring Member of the Paintbrush Tuff from drillhole UE-25A#1 core for strontium and neodymium isotopes, and selected trace elements to further constrain the origin of a zeolitized zone associated with the lower vitrophyre. The results of this study will be presented at the symposium on "Scientific Basis for Nuclear Waste Management XIV" at the fall meeting of the Materials Research Society (MRS) in Boston, Massachusetts (November 26-December 1, 1990).

USGS staff prepared an extended abstract for a paper entitled "Assessing the Natural Performance of Felsic Tuff at Yucca Mountain Using the Rb-Sr and Sm-Nd Systems--A Study of the Altered Zone in the Topopah Spring Member, Paintbrush Tuff" (Marshall and Peterman). This will be presented at the ANS Spring Meeting in Las Vegas in 1991. Staff revised a manuscript on carbonates from Trench 14 and Busted Butte for inclusion in a USGS Bulletin. The staff also wrote software procedures for conducting accurate analyses of selected trace elements in core and outcrop samples from Yucca Mountain and a technical procedure on Spike Preparation; continued strontium mass spectrometric analyses of samples from Yucca Mountain, prepared and analyzed by energy dispersive x-ray fluorescence (XRF) samples of carbonate collected from trenches and discharge areas in Crater Flat; presented results of strontium isotopic study of carbonates to Szymanski Peer Review Panel in June 1990; continued strontium isotope analyses of ground-water samples from southern Nevada; and participated in a field trip to the Ruby Mountains, Nevada, analog area. The staff also attended three specialized training courses in energy dispersive XRF instrumentation and technical procedure preparation and compliance, and provided technical support for a software QA workshop on August 7, 1990, as well as other software meetings.

The review and formatting of lithologic descriptions of samples of drill-bit cuttings from the existing 18 WT holes was completed for preparation of a report on the lithology and stratigraphy of these boreholes. Some preliminary scoping work was conducted on selected samples using an electron microprobe.

RIB CR41, Topographic Map, which is a topographic map of the proposed repository surface facility area, was reviewed.

A technical procedure on Volcanic Stratigraphic Studies was informally reviewed, and revisions were discussed with Project personnel.

The following papers were submitted for publication: (1) "Redistribution of Selected Trace Elements at Yucca Mountain - A Record of Localized Rock Water Interaction" (Spengler and Peterman), submitted for inclusion into a USGS Bulletin; (2) Distribution of Rubidium, Strontium, and Zirconium in Tuffs from Two Deep Coreholes at Yucca Mountain, Nevada" (Spengler and Peterman), submitted to the 1991 International Topical Meeting on High Level Radioactive Waste Management; and (3) "Scientific Basis for Nuclear Waste Management XIV" and "Assessing the Natural Performance of Felsic Tuffs at Yucca Mountain Using the Rb-Dr and Sm-Nd Systems - A Study of the Altered Zone in the Topopah Spring Member of the Paintbrush Tuff" (Peterman et al.) submitted to the MRS.

USGS staff visited and assessed the geologic setting at the Swedish hard rock laboratory on the island of Aspo during the second technical exchange on site stratigraphy, structure, and neotectonics, held in Sweden August 23 to September 2, 1990. This effort is part of the DOE's International Program. Focus of the meeting was geophysical characterization of site structural and lithologic features.

Activity 8.3.1.4.2.1.2 - Surface-Based Geophysical Surveys. Milestone isostatic gravity and merged aeromagnetic maps of the NTS by Ponce et al. (1988) and Kirchoff-Stein et al. (1989) were released and distributed to USGS, DOE, and NRC participants in the Yucca Mountain Project.

The important compendium of all gravity data at the NTS collected by the USGS and other government labs since 1957 was released in a landmark report, "Principal Facts for about 16,000 Gravity Stations in the NTS and Vicinity" USGS Open-File Report 89-682-A, by Harris et al. (1989).

The staff presented a summary of major geophysical results to the NAS/ National Research Council panel at the University of Hawaii on July 26 and 27, 1990, and participated in a Swedish Technical Exchange Meeting in Stockholm and Aspo.

A report is being prepared titled "Status of Regional Geophysics Investigations, Yucca Mountain Project" (Oliver and Ponce); this report contains 10 chapters, covering a variety of geophysical methods.

Activity 8.3.1.4.2.1.3 - Borehole Geophysical Surveys. A major effort was focused on the analysis of the existing set of logs from Yucca Mountain to produce quantitative estimates of bulk density, porosity, water saturation, and qualitative estimates of fracturing and alteration. This effort made use of the extensive data base that was compiled in May 1989. Performing the computations required devising algorithms to convert logging measurements to the desired physical quantities, establishing a conversion for the density log, and validating the results. A Birdwell density tool was calibrated at NTS in March 1990, and the results were confirmed by close examination of the logs. Other independent measurements of density from the laboratory and from

gravimeter logs have been used to confirm the density algorithm. The density calibration work is now essentially complete. Excellent use was made of mineralogical data from LANL. A disk of LANL data was acquired and converted to volume percent and incorporated with first-pass estimates of porosity. The mineralogy log allows a better understanding of the physical-property measurements obtained from both core and logs. These insights have been summarized in an article for a USGS Bulletin.

Members of the Project were involved in the planning phase of the Apache Leap borehole, in the hope that logs and core from the hole could be used to improve calibration of some Atlas Wireline Service (AWS) tools in air-filled holes. Unfortunately, water from a perched zone leaked through the casing, and most of the drilling was done under wet conditions, so that Project objectives were not totally fulfilled. Calibration of the AWS tools in air-filled holes remains a significant unresolved problem for the future.

It has been proposed that both AWS and Schlumberger logs be run in an existing deep hole at Yucca Mountain. The AWS tools would be run to examine some of the newer equipment not previously used at Yucca Mountain. Schlumberger has a "geochemical" logging tool that uses neutron activation techniques to obtain elemental concentrations, which can then be transformed to mineralogical content. The tool has not been used in air-filled boreholes, and much work is required to determine if it can be used in this medium, and to then develop the appropriate mineral transforms.

The magnetic field tool was used to log three boreholes at the NTS, under funding from the Defense Nuclear Agency. This enabled establishment of calibration procedures for the tool and elimination of some problems in the software. New centralizers were built and are being modified. Continued temperature drift problems with the magnetic susceptibility tool make it necessary to modify that tool; a design has been prepared, but modification has not started. The upgrade of the data acquisition system in the logging truck is underway.

Project staff attended the peer review meeting for seismic reflection and refraction on September 11 and 12 at the Project Office; a synopsis of the physical properties of the tuffs, with emphasis on density, velocity, and a synthetic seismogram derived from logs, was presented.

The Project staff participated in the U.S.-Swedish bilateral exchange in Oskarshamn, Sweden, during the week of August 27-31, 1990. A comparative approach to log analysis was the subject of the U.S.-Swedish exchange. The staff participated in the USGS-CASY symposium "Fractures, Hydrology, and Yucca Mountain" held in Golden, Colorado, on September 13 and 14. A poster titled "Fracture Counts from Borehole Logs" (Nelson and Snyder) was presented. The symposium was valuable in pointing out the difficulty in obtaining statistically meaningful hydrological responses from currently available borehole data.

Activity 8.3.1.4.2.1.5 - Magnetic Properties and Stratigraphic Correlations. Staff reviewed a manuscript dealing with paleomagnetic documentation of vertical-air rotation at Yucca Mountain after the manuscript had been reviewed by the Journal of Geophysical Research. Most effort was spent in reading and analyzing large amounts of rock magnetic data from the

Tiva Canyon Member of the Paintbrush Tuff for drillholes USW GU-3 and USW VH-2.

2.2.3.4 Study 8.3.1.4.2.2 - Characterization of the Structural Features within the Site Area

Comment response forms for two additional activities in Study Plan 8.3.1.4.2.2 were returned to USGS on August 21, 1990, and the preparation of responses to comments is proceeding.

Activity 8.3.1.4.2.2.1 - Geologic Mapping of Zonal Features in the Paintbrush Tuff. The following papers were submitted for publication in a USGS Bulletin: "Neotectonics and Low-Angle Extensional Faulting at Yucca Mountain and Vicinity" (Meyers et al.) and "Potential Effects of Quaternary Tectonism on the Hydrology of Yucca Mountain" (Fox et al.).

A report entitled "Geologic Framework and Cenozoic Evolution of the Yucca Mountain Area, Nevada" (Fox et al., 1990) was submitted to the proceedings volume of the International Symposium on Unique Underground Structures, held in Denver on June 12-15, 1990.

USGS staff participated in the UZ Hydrology Peer Review, held in Las Vegas on June 4-6, 1990, and made a presentation titled "Geologic Anisotropy in the Unsaturated Zone" (Spengler).

The staff reviewed the Swedish R&D-Programme 89, Handling and Final Disposal of Nuclear Waste, and reviewed the background report to the R&D Programme 89; based on this review, staff made recommendations regarding possible areas of participation in the Swedish Hard Rock Laboratory.

Project staff helped organize a three-day seminar (August 20-22, 1990) entitled "Laboratory Analysis of Volcanic Rocks--Emphasis on Yucca Mountain" and attended a laboratory instrumentation workshop.

Activity 8.3.1.4.2.2.2 - Surface Fracture Network Studies. Revisions were made to the Project Graded Quality Assurance Exceptions and Controls Table for Activity 8.3.1.4.2.2.2 in April 1990.

With the recent restart of the uncleared outcrop studies, data collection has resumed and is currently focused at Yucca Mountain and Fran Ridge. Authorization to return to work for non-surface disturbing parts of Activity 8.3.1.4.2.2.2 was granted on March 19, 1990. To date, fracture studies have been completed or nearly completed at 12 stations; 9 stations are located in the Tiva Canyon Member of the Paintbrush Tuff, and the remaining stations are located in the Topopah Spring Member. Preliminary results indicate that a definable fracture pattern is present and separate fracture sets can be recognized and characterized from surface exposures.

A paper on mapping linear features at Yucca Mountain from large-scale aerial photographs was submitted for a USGS Bulletin.

An oral presentation on statistical properties of real fracture networks was presented on September 12, 1990, at the USGS-CASY-sponsored symposium on

"Fractures, Hydrology, and Yucca Mountain." An abstract titled "Some General Properties of Joints and Joint Networks in Horizontally Layered Sedimentary and Volcanic Rocks--An Overview" (Throckmorton) was submitted for the symposium.

A summary of significant fracture information was prepared for use at the UZ Hydrology Peer Review, June 4-8, 1990, Las Vegas, Nevada. Summary information was also prepared for use at the DOE/NRC Technical Exchange on Significant Faults, June 12-13, 1990, Las Vegas, Nevada. Responses to NRC comments on the SCP were prepared.

Workshops, meetings, and field trips attended included (1) a three-day NTS Petrography-SEM Seminar (August 20-22, 1990); (2) a one-day field trip to Boulder, Colorado, to study fault-slip analysis techniques (August 3, 1990); and (3) a one-day USGS-CASY Seminar (May 1990).

Activity 8.3.1.4.2.2.3 - Borehole Evaluation of Faults and Fractures. The staff cross-checked and reviewed Television Camera and Acoustic Televiewer logs (data sheets and films) of existing holes in which both logs were run, in order to compare the capability of each to show borehole fractures. Fracture-coating data from core logs from boreholes USW G-2/GU-3 were compiled; these data will be included in a report along with already published data from boreholes USW G-1 and USW G-4.

The staff prepared the USGS response to a request from LANL, ESF Test Manager's Office, for secondary choices for locations of additional drifts needed to intersect the Ghost Dance fault and any other N-S trending faults at the repository level.

A poster titled "Fracture Counts from Borehole Logs" (Nelson and Snyder) was presented at the September USGS-CASY meeting in Denver (September 13). A technical review was completed of a manuscript titled "Fracture Characteristics in Core from Drill Hole USW G-4, Yucca Mountain, Nye County, Nevada" (Barton et al.).

The technical procedures on Borehole Video Fracture Logging and on Fracture Logging from Acoustic Televiewer Images were reviewed and revised by the staff. They also reviewed a preliminary report from the Soils/Fractures Working Group and attended a meeting of a Technical Working Group on Faulting within the Yucca Mountain area. In addition, the staff attended two Sample Overview Committee meetings at Apache Leap, Arizona.

Activity 8.3.1.4.2.2.4 - Geologic Mapping of the Exploratory Shaft and Drifts. Staff completed modifications to a commercial GIS package (Kork Systems KGIS). Modifications were designed, programmed, and installed enabling relational geographic queries in three dimensions for multi-point, non-linear data corresponding to fracture and lithology data collected from underground geologic drifts and shafts. The pseudo three-dimensional coordinate data base has been built on extensions to the University of Maine PANDA data base, and is transparently linked to a standard implementation of ORACLE (a relational data base for storing geologic attribute data), providing full relational query capability for attribute data. Photogrammetric data collected from stereo pairs of photographs have been batch translated from simple "spaghetti" strings of ASCII data to predefined topologic elements

based on macros of user-selectable library calls to PANDA. Preliminary testing reveals that this implementation will facilitate storage and retrieval of topologically-structured data for use in three-dimensional fracture-characterization studies. Future work will focus on interactive editing of three-dimensional data either through on-line photogrammetric projection, or independently using three-dimensional computer-aided design (CAD) and surface modeling technology.

QA documentation for GEOPROGRAM (a program to collect geologic information from oriented stereo-photographs) was submitted, reviewed, and approved by the software configuration control committee. QA documentation for ORIPROGRAM (a program used for orienting stereophotographs in an analytical plotter) was submitted, reviewed, and minor modifications are being made prior to approval. Also, technical procedures for underground shaft and drift mapping were submitted for review. Preparation of technical procedures for photogrammetric trench mapping was initiated.

Project investigators (1) finished a detailed position paper describing the need for small-scale fracture data, including how the information will be used in site characterization and the effects of mining method on fracture mapping; (2) continued investigating downhole cameras for preliminary geologic mapping machine-bored shafts; (3) performed further prototype field testing of the photogrammetry equipment and procedures at the USBR Roosevelt Dam Lake Tap Tunnel; and (4) provided an informational demonstration of the photogrammetric equipment, methods, and results.

Project staff also participated in a USGS/LANL/DOE meeting to determine impacts on the testing of ESF Alternative options 18-34 (rapid access to Calico Hills) on ESF investigations. Participants completed a questionnaire on the impact of delaying Underground Geologic Mapping, as a part of the study for ESF Alternative options 18-34.

Activity 8.3.1.4.2.2.5 - Seismic Tomography/Vertical Seismic Profiling. The paper entitled "The Application of Vertical Seismic Profiling and Cross-Hole Tomographic Imaging for Fracture Characterization at Yucca Mountain" (Majer et al.) was presented at the International Topical Meeting on High Level Radioactive Waste Management in Las Vegas, Nevada, on April 10, 1990. This paper was revised in accordance with USGS reviews, and submitted for inclusion in a USGS Bulletin.

Some modeling work was performed to evaluate the application of reverse VSP using the drill bit as a source. This would have a great advantage where subsurface information is limited by providing information prior to deep-hole access and possibly providing a look ahead for drilling planning.

The modeling codes ANRAY90 and RAY87 were modified for easy user interaction. Due to access problems at Yucca Mountain, discussions were held with TOMEX Inc. to determine if VSP during drilling would be applicable for three-component recording. Preliminary modeling was started to answer these questions.

2.2.3.5 Study 8.3.1.4.2.3 - Three-Dimensional Geologic Model

No progress was made in the development of this study plan during the reporting period.

2.2.3.6 Study 8.3.1.4.3.1 - Systematic Acquisition of Site-Specific Subsurface Information

Activity 8.3.1.4.3.1.1 - Systematic Drilling Program. The study plan for the Systematic Drilling Program has been in Project Office and DOE/HQ review. Change Requests to the Technical Planning Basis may be required as part of the comment resolution process related to review of the study plan for this activity, now underway. The actual scope of such changes is not known at this time, although major redirections of effort are not expected.

An SNL experiment procedure was prepared for scoping studies to define the magnitude of spatial correlation expected for several major rock properties of interest. This work will involve geostatistical evaluation of rock properties measured on samples taken from tuffs at Yucca Mountain, elsewhere at the NTS, and at other analogous locations.

C. A. Rautman presented "Applications of Geostatistics to Rock Properties Modeling at the Yucca Mountain Nuclear Waste Repository Site" at the Rocky Mountain Section meeting of the GSA, Jackson, Wyoming, in May.

2.2.3.7 Study 8.3.1.4.3.2 - Three-Dimensional Rock Characteristics Models

Activity 8.3.1.4.3.2.1 - Development of Three-Dimensional Models of Rock Characteristics at the Repository Site. Preliminary planning progressed for this non-site study, which involves the modeling of site data collected by numerous other site-oriented studies. The study plan for this activity is scheduled to be completed in December 1993.

Investigations of newly emerging geostatistical modeling techniques continued to yield useful results. SNL staff created simulated models of porosity and unsaturated permeability that are conditioned to existing data from Yucca Mountain. The simulations reproduce measured values at their locations, reproduce the overall histogram of measurements, and generally reflect the patterns of spatial continuity used as input. These models are realistic preliminary representations of those rock properties in nature. The application of new techniques and computer software to actual situations provided an outline of the work that will be required when data from site characterization are available. Software requirements are also being identified.

2.2.4 Climate (SCP Section 8.3.1.5)

2.2.4.1 Study 8.3.1.5.1.1 - Characterization of Modern Regional Climate

Activity 8.3.1.5.1.1.1 - Synoptic Characterization of Regional Climate. Work continued on development of a data base on modern climate parameters for the western United States.

2.2.4.2 Study 8.3.1.5.1.2 - Paleoclimate Study: Lake, Playa, and Marsh Deposits

Study Plan 8.3.1.5.1.2 has been through formal USGS review and is presently being revised by the author.

Activity 8.3.1.5.1.2.1 - Paleontologic Analysis. Project personnel have (1) organized modern and fossil diatom and chrysophyte samples for use in paleolimnological research; (2) completed a draft of the study plan for lakes, playas, and marshes; and (3) conducted analog field work in Ruby Valley, Nevada.

2.2.4.3 Study 8.3.1.5.1.3 - Climatic Implications of Terrestrial Paleoecology

Study Plan 8.3.1.5.1.3 draft preparation is nearly completed. Formal USGS review is anticipated in October 1990.

Activity 8.3.1.5.1.3.3 - Determination of Vegetation-Climate Relationships. Project personnel attended two planning sessions with DOE on future climate modeling at the NCAR (Boulder, Colorado), completed a draft of the study plan for "The Climatic Implications of Terrestrial Paleoecology," and worked on a data base of modern climate data.

2.2.4.4 Study 8.3.1.5.1.4 - Analysis of the Paleoenvironmental History of the Yucca Mountain Region

Study Plan 8.3.1.5.1.4 review comments were received from the Project Office on July 18, 1990, and from DOE/HQ on August 13, 1990. The staff are presently preparing for a comment resolution meeting scheduled for October 1990.

Activity 8.3.1.5.1.4.1 - Modeling of Soil Properties in the Yucca Mountain Region. A draft report was written on the morphology and genesis of soils on the Kyle Canyon fan, Nevada. This report fulfills one of the important milestones of the activity on modeling of soil properties in the Yucca Mountain region; the report is being revised following technical review. Data derived from field descriptions and chemical, mineralogical, and microscopic analyses of soils are combined with data from extensive age-dating efforts and analyses of modern eolian dust to arrive at several significant conclusions regarding soil genesis and rates of soil development. The report is intended for publication as a journal article.

The staff monitored the analyses of dust samples collected in fall 1989 by the contractor at the University of Colorado, Institute of Arctic and Alpine Research, and completed a draft report titled "Morphology and Genesis of Calcic Soils on the Kyle Canyon Fan, Nevada" (Reheis et al.).

Activity 8.3.1.5.1.4.2 - Surficial Deposits Mapping of the Yucca Mountain Area. Project staff responded to comments returned from DOE's review of the study plan titled "Analysis of the Paleoenvironmental History of the Yucca Mountain Region." Staff participated in a field trip to Yucca Mountain for the NWTRB and the NRC Technical Exchange in June 1990; staff also presented an explanation of the USGS Quaternary Faulting within the Site Area study plan at that exchange.

2.2.4.5 Study 8.3.1.5.1.5 - Paleoclimate-Paleoenvironmental Synthesis

No progress was made in the development of this study plan during the reporting period.

2.2.4.6 Study 8.3.1.5.1.6 - Characterization of the Future Regional Climate and Environments

The contract has been accepted by the NCAR to develop a regional climate model of Yucca Mountain for the next 10,000 years. The model will provide estimates of the net precipitation-evapotranspiration rates. The NCAR staff completed the software QA training and the follow-up QA audit. At the organizational workshop on climate modeling on April 3, 1990, in Boulder, Colorado, the current status of various activities was discussed and future plans were developed. The first draft of the study plan was prepared and is scheduled to be completed in October 1990. On August 7, a meeting on co-ordinating climate and hydrological modeling was held at the NCAR in Boulder. A working group was formed to establish a joint project on this topic.

Activity 8.3.1.5.1.6.1 - Global Climate Modeling. The GENESIS global model is ready for the final test phase. A beta-test version of GENESIS will be available to the global modeling group during the latter part of 1990.

Activity 8.3.1.5.1.6.2 - Regional Climate Modeling. One year of prevalidation simulations with the Mesoscale Model 4 (MM4) regional climate model were completed. A solicited presentation on regional climate modeling was delivered by F. Giorgi of the NCAR at the Enrico Fermi International School of Physics in Varrenna, Italy, in July 1990.

Activity 8.3.1.5.1.6.4 - Empirical Climate Modeling. Project personnel continued library research and entry of modern climate data into a data base in preparation for climate model development.

2.2.4.7 Study 8.3.1.5.2.1 - Characterization of the Quaternary Regional Hydrology

Comments and questions by NRC concerning Study Plan 8.3.1.5.2.1, Activities 3,4, and 5, were received by DOE. Responses are currently under

development. Revision 1 of Study Plan 8.3.1.5.2.1, containing a description of the Regional Paleoflood Evaluation, was submitted to the Project Office for review on September 25, 1990.

Activity 8.3.1.5.2.1.1 - Regional Paleoflood Evaluations. The study plan for Activity 8.3.1.5.2.1.1 was completed. It was then given colleague review within the USGS for technical feasibility and acceptability. Colleague review comments have been resolved by the author and the plan has been submitted to DOE for their review.

Literature review of paleoflood information, techniques of investigations, and prospective areas of study in the Yucca Mountain region continued. New candidate areas for future study were discovered during field monitoring of streamflow, flooding, and hazardous debris transport during the summer of 1990. Results and techniques of non-Project geomorphic studies in the region have been examined for the availability of paleoflood information. Some field consultation has been done with non-Project geomorphologists regarding strategies of paleoflood investigation.

Activity 8.3.1.5.2.1.2 - Quaternary Unsaturated-Zone Hydrochemical Analysis. An Interim Change Notice was submitted by the USGS to the Project Office proposing that Activity 8.3.1.5.2.1.2 be deleted from Study Plan 8.3.1.5.2.1. The deletion was recommended because the scope of this activity will be accomplished under Study Plan 8.3.1.2.2.7, Hydrochemical Characterization of the Unsaturated Zone.

Activity 8.3.1.5.2.1.3 - Evaluation of Past Discharge Areas. A field trip was conducted to Amargosa Valley, Crater Flat, and Jackass Flats to collect soil and vegetation community data for a regional vegetation map. Data were collected at 60 sites throughout the study area during a three-week field trip. Vegetation numeration transects were conducted, and soil and pollen samples for analysis were also collected among the transects. Samples of the upper crust of the soil surface were collected for ground-truth data for remote-sensing-image interpretation.

A field trip was conducted to the Ruby Valley area of northeast Nevada. This area was chosen because it is considered by many investigators to be a modern analog to the Las Vegas Valley from 14,000 to 20,000 years ago. During the trip, 25 spring sites were collected for water chemistry. The springs were also collected for their contained aquatic flora and invertebrate fauna. The data collected are intended to record the biological responses to differences in thermal, concentrational, compositional, and flow characteristics of ground-water discharge sites that are in close geographic proximity to each other.

Existing samples from Zuni Salt Lake, New Mexico, were examined for ostracode and diatom content in order to evaluate the potential of this site for late Pleistocene and Holocene ground-water level studies. The preliminary examination has shown that abundant microfossils exist in the samples. If these samples can be dated, this site could serve as a record of past ground-water level variations.

All of the modern spring and seep samples collected during July have been processed and extraction of ostracodes and charophytes for study is underway.

About 100 chrysophyte samples from springs and seeps and related environments have been processed. A revision of the technical procedure dealing with the preparation of diatoms was completed. Project personnel continued organization of modern and fossil diatom collections for future research activities. Project personnel attended an important meeting on climate and hydrological modeling at the NCAR conducted by DOE/HQ staff. The Project needs for climate data for future modeling were indicated to conference participants.

Activity 8.3.1.5.2.1.4 - Analog Recharge Studies. Three quarterly field trips and one special trip were completed to the analog recharge sites in central Nevada during the reporting period April-September. Yearly calibration and maintenance of the equipment at the analog sites was completed during the regularly scheduled quarterly field trips.

The USGS automated data-processing system (ADAPS) was successfully installed on the USGS Prime computer. This allows the management and manipulation of field data for input into future models. Five years of weather data have been entered into ADAPS for one site, and work has started on entering the data from the other site.

Six digital maps which represent the slope, aspect, and elevation of the analog sites were produced by digitizing and processing published topographic maps using ARC/INFO. This is critical to the eventual division of the study areas into hydrologic response units and the modeling of the areas hydrologic character.

Two reports went through the review process: "Origin of Ground Water in the Yucca Mountain Area, Nevada--An Analog Study" (McKinley) and "Chemical Analysis of Water from Selected Wells and Springs in the Yucca Mountain Area, Nevada and South-Eastern California" (McKinley et al.). The latter report has received approval for publication.

Initial work has started to test the hypothesis that tuffaceous material is quickly leached of available chloride by water.

Arid Zone Geochemistry personnel attended the evapotranspiration workshop in Carson City, Nevada, and gained improved understanding of the abilities and limitations of meteorological equipment and the paradigms on which the interpretation of meteorological data is based.

Bulk precipitation samples continued to be collected quarterly from the vicinity of the two National Atmospheric Deposition Program sites in southern Arizona. Developmental work continued on the design of the aerosol collectors.

Arid Zone Geochemistry personnel met with the soils mapping contractor on site at the Organ Pipe Cactus National Monument to discuss the progress of the mapping effort. The field work is now completed. The tower installation contractor was shown the site where tower installation will take place in October 1990.

Activity 8.3.1.5.2.1.5 - Studies of Calcite and Opaline-Silica Vein Deposits. A draft manuscript, "Preliminary Study of Lead Isotopes in the

Carbonate-Silica Veins of Trench 14, Yucca Mountain" (Zartman and Kwak), was completed for inclusion in a USGS Bulletin.

A draft was completed of a scientific notebook procedure that will allow experimentation and development of a new procedure for analyzing the isotopic composition of lead in vein carbonates. The current procedure may not be yielding a complete separation of silicate and carbonate phases, and QA auditors suggested that a notebook procedure be used rather than modifying the technical procedure until the final technique (if any) was determined.

Carbonate-silica vein samples were analyzed for uranium, thorium, and lead content and lead isotopic composition as part of integrated field and laboratory study of the origin of Trench 14 hydrogenic deposits.

The geochemical procedure for separation of lead from vein carbonate was revised, and work was initiated on revisions of the Uranium-Thorium-Lead Isotope Geochemistry procedure. Revision of the technical procedure supporting carbonate stable-isotope studies was completed, and a further revision to accommodate recent changes in the handling of software QA for automated instrumentation is in progress. Revision began of the geochemical procedure for stable-isotope studies of opaline silica.

A draft paper titled "Stable Isotope Geochemistry of Fault- and Fracture-Hosted Calcite and Ground-Water Carbonate, Yucca Mountain Area" (Whelan and Stuckless) was completed for inclusion in a USGS Bulletin. A paper entitled "Reconnaissance ^{13}C and ^{18}O Data from Trench 14, Busted Butte, and Drill Hole G-4, Yucca Mountain, Nevada Test Site" (Whelan and Stuckless, 1990) was published in the Proceedings of the International Topical Meeting on High Level Radioactive Waste Management.

Ostracode collection continued from selected ground-water discharge sites in California. This year pH, conductivity, and temperature data were routinely collected at each site. The results from the collection of the first year have been summarized in a manuscript, which is now in review.

2.2.4.8 Study 8.3.1.5.2.2 - Characterization of Future Regional Hydrology Due to Climate Changes

A draft of Study Plan 8.3.1.5.2.2 was completed and submitted for internal USGS technical review.

Activity 8.3.1.5.2.2.1 - Analysis of Future Surface Hydrology Due to Climate Changes. Literature review of precipitation-runoff modeling continued, and several modeling codes were evaluated for usefulness as numerical tools to facilitate the study of future surface hydrology in the vicinity of Yucca Mountain. Boundaries of drainage basins in Fortymile Wash, Crater Flat, and other basins tributary to the upper Amargosa River were delineated, digitized, and entered into a GIS.

Activity 8.3.1.5.2.2.3 - Synthesis of Effects of Possible Future Recharge Due to Climate Changes on Hydrologic Characteristics of the Yucca Mountain Saturated Zone. A 386 computer assigned to the project is dedicated to the Geoscientific Information System (GSIS). GSIS uses the TYDAC Spatial Analysis

System (SPANS) which is a raster-based GIS data base and data analysis system. Geologic maps from the Geologic Division in the Amargosa Desert, Crater Flat, and Jackass Flats areas are being prepared for inclusion in the SPANS system. These maps are prepared with gross geologic units, scanned, and various geologic units are attributed. The data are then stored and indexed in the SPANS system for further analysis and use in regional ground-water models.

An abstract explaining the GSIS methods has been prepared for presentation at the Annual Dynamic Graphics International Users Conference. An abstract explaining the potential application of three-dimensional GSIS for regional ground-water modeling has received approval for presentation to the AGU and three-dimensional computer graphic meeting at Freiberg, West Germany (Turner et al., 1990).

2.2.5 Erosion (SCP Section 8.3.1.6)

2.2.5.1 Study 8.3.1.6.1.1 - Distribution and Characteristics of Present and Past Erosion

Activity 8.3.1.6.1.1.3 - Analysis of Hillslope Erosion at Yucca Mountain. USGS and LANL investigators completed an analysis of older hillslope deposits on Yucca Mountain and submitted a manuscript for review in August 1990 entitled "Relict Colluvial Boulder Deposits, Indicators of Slope Stability and Climatic Change in the Yucca Mountain Region, Southern Nevada" (Whitney and Harrington). Older colluvial hillslope deposits on Yucca Mountain were dated by cation-ratio dating of rock varnish accreted on boulder surfaces. Three additional older deposits on nearby Skull and Little Skull Mountains were also dated.

Project investigators also completed an analysis of hillslope erosion of Buckboard Mesa and Yucca Mountain. Results of this analysis were submitted (August 1990) in a summary to the ANS for consideration as a talk and paper at the 1991 International Topical Meeting on High Level Radioactive Waste Management.

2.2.5.2 Study 8.3.1.6.2.1 - Influence of the Effects of Future Climate on Erosion

No progress was made in the development of this study plan during the reporting period.

2.2.5.3 Study 8.3.1.6.3.1 - Evaluation of the Effects of Future Tectonic Activity on Erosion

No progress was made in the development of this study plan during the reporting period.

2.2.6 Postclosure Tectonics (SCP Section 8.3.1.8)

2.2.6.1 Study 8.3.1.8.1.1 - Probability of a Volcanic Eruption Penetrating the Repository

The study plan was revised and submitted to the Project Office for comment verification. Comment verification was completed, and the study plan was submitted to DOE/HQ for transmittal to the NRC.

A paper, "Basaltic Volcanic Episodes of the Yucca Mountain Region" (Crowe, 1990), was published in the proceedings for the first annual International Topical Meeting on High Level Radioactive Waste Management.

Activity 8.3.1.8.1.1.1 - Location and Timing of Volcanic Events. No progress during the reporting period.

Activity 8.3.1.8.1.1.2 - Evaluation of the Structural Controls of Basaltic Volcanic Activity. Three approaches for calculating the probability of disruption of the repository were presented in a talk at the International Topical Meeting on High Level Radioactive Waste Management in Las Vegas (Crowe, 1990). The first approach uses a regression fit of the geographic coordinates of Pliocene and Quaternary volcanic centers (latitude and longitude). Using the regression fit, the confidence interval resulting in intersection of the repository is calculated. The second approach assumes structural control of the Crater Flat volcanic zone and calculates the mean and standard deviation of the dispersion distance of centers from this structural zone. The third approach assumes the Lathrop Wells volcanic center is the first of an impending cluster of centers. Mean lengths of volcanic clusters in the Yucca Mountain region are used to establish the likelihood of intersection of the repository.

A probabilistic approach modified by expert opinion will be used to establish the disruption parameter (structural controls) for future volcanic activity. The probability approach will emphasize using multiple models of the disruption parameter to construct a probability histogram or distribution function. Further work to discriminate the models will be undertaken only if the models change the probability distribution.

A talk was presented at a special symposium at the University of New Mexico. The talk was entitled "The Role of the Geologist in Risk Assessment: Examples from Volcanology Studies." Data were presented from volcanism studies for the Yucca Mountain site to illustrate how a probabilistic perspective is used for risk assessment.

Activity 8.3.1.8.1.1.3 - Presence of Magma Bodies in the Vicinity of the Site. No progress during the reporting period.

Activity 8.3.1.8.1.1.4 - Probability Calculations and Assessment. A data acquisition system was obtained for the laser theodolite to facilitate rapid surveying of volcanic centers. The data will be used to calculate magma volumes of volcanic units for probability calculations. A recurrence rate model was developed for the time patterns of Pliocene and Quaternary basaltic volcanism in the Yucca Mountain region. This model assumes that basalt centers form as clusters in a relatively brief period of time. Sensitive

parameters of a cluster-based, recurrence rate model are whether the basalt of Buckboard Mesa is included in the model and the age of the Lathrop Wells volcanic center. Revised magma volumes were determined for the Lathrop Wells, Hidden Cone, and Little Black Peak cones. Revised calculations were completed of the recurrence rate of volcanic events assuming a stochastic rate model. These revised calculations used current chronology data for the Pliocene and Quaternary centers in the Yucca Mountain region.

2.2.6.2 Study 8.3.1.8.1.2 - Effects of a Volcanic Eruption Penetrating the Repository

The study plan is in preparation.

Activity 8.3.1.8.1.2.1 - Effects of Strombolian Eruptions. A talk was presented to the performance assessment group at SNL on probability approaches used for volcanism studies. The discussion included scenario models for magmatic disruption and how the problem could be bounded using a probabilistic approach. The event trees developed for volcanism by the performance assessment group were reviewed.

Activity 8.3.1.8.1.2.2 - Effects of Hydrovolcanic Eruptions. No progress during the reporting period.

2.2.6.3 Study 8.3.1.8.2.1 - Analysis of Waste Package Rupture Due to Tectonic Processes and Events

Study Plan 8.3.1.8.2.1 is being revised following receipt of Project Office review comments.

2.2.6.4 Study 8.3.1.8.3.1 - Analysis of the Effects of Tectonic Processes and Events on Average Percolation Flux Rates Over the Repository

No progress was made in this study during the reporting period. This is an out-year study.

2.2.6.5 Study 8.3.1.8.3.2 - Analysis of the Effects of Tectonic Processes and Events on Changes in Water-Table Elevation

No progress was made in this study during the reporting period. This is an out-year study.

2.2.6.6 Study 8.3.1.8.3.3 - Analysis of the Effects of Tectonic Processes and Events on Local Fracture Permeability and Effective Porosity

A draft of Study Plan 8.3.1.8.3.3 is in preparation.

2.2.6.7 Study 8.3.1.8.4.1 - Analysis of the Effects of Tectonic Processes and Events on Rock Geochemical Properties

No progress was made in this study during the reporting period. This is an out-year study.

2.2.6.8 Study 8.3.1.8.5.1 - Characterization of Volcanic Features

The study plan was accepted by the NRC. An internal QA survey of the activities of this study was completed. Five deficiency reports were issued, which were resolved within 60 days of the survey.

Activity 8.3.1.8.5.1.1 - Volcanism Drill Holes. No progress during the reporting period.

Activity 8.3.1.8.5.1.2 - Geochronology Studies. A sampling trip was made to the Cima volcanic field to attempt to choose a sampling site for geochronology measurements using the ^{238}U-^{232}Th disequilibrium, the $^{3}He/^{4}He$, the ^{10}Be, and the ^{26}Al dating methods. Because of the large sample sizes required for the latter two techniques, no suitable sites for sampling were identified. Preliminary paleomagnetic data were obtained by the USGS for the Sleeping Butte centers and two basalt episodes of Crater Flat. The USGS conducted an internal audit of the USGS work on potassium-argon (K-Ar) dating and paleomagnetic studies. Significant deficiencies in the studies were identified. LANL QA issued an order that the USGS data should not be used until the deficiencies are corrected.

A ^{238}U-^{232}Th isochron age was obtained for the Ql5 unit (lava), Ql4 (lava), and Ql1 unit (summit of the cone) at the Lathrop Wells volcanic center for surface exposure dating using the $^{3}He/^{4}He$ method. A series of experiments was completed to assess the extent and rate of anomalous fading of the thermoluminescence (TL) signal from soil samples for the Lathrop Wells center. The results confirm minimal problems from anomalous fading with these samples. TL ages were determined for a sample from the A cone at the Cima volcanic field and a sequence of soils with interbedded tephra from the Lathrop Wells volcanic center. Results are consistent with geomorphic and soils correlations between the centers.

Activity 8.3.1.8.5.1.3 - Field Geologic Studies. Field studies were completed at the Cima volcanic field to select volcanic centers for detailed studies. Identified centers include the A, B, G, H, and I cones. A new vent sequence was identified at the A cone. Field, petrologic, and geomorphic criteria were developed for identifying lava flows of the H and I center. Field, geomorphic, and soil data were identified that indicate the G cone is a polycyclic center. Hydrovolcanic deposits were identified as part of early eruptive events at all centers except the A cone. A geologic map was completed of the Sleeping Butte volcanic centers. The map was drafted and a report written that accompanies the map. The map and report will be published during the next reporting period. A talk was presented at the CASY symposium at USGS/Denver. The talk emphasized the results of filed and chronology studies of the Lathrop Wells volcanic center. Three models were presented to attempt to explain the current understanding of the results of chronology studies at the Lathrop Wells center. An inconsistency was identified between

the results of stratigraphic, geomorphic, and soils studies at the center and the results of paleomagnetic studies. A talk was presented in Hawaii at the meeting of the NAS panel on coupled processes. The talk summarized the history of basaltic volcanism in the Yucca Mountain region, noted the small volume of basalt eruptions in the Quaternary, and discussed data regarding the presence or absence of magma chambers in the crust beneath the Yucca Mountain region.

Activity 8.3.1.8.5.1.4 - Geochemistry of Scoria Sequences. Instrumental neutron activation analysis (INAA) data were obtained for the lavas of the Lathrop Wells volcanic center to determine if there were sufficient differences in U-Th content to establish a ^{238}U-^{232}Th isochron using separate flows. The resulting data indicated the U-Th content of the flows is too similar to use this method. Sample collection was completed for the Lathrop Wells volcanic center. A subset of the samples was submitted for INAA. Proton induced x-ray emissions (PIXE) data were evaluated statistically for basalt ashes in trench deposits and pyroclastic units at the Lathrop Wells volcanic center.

Activity 8.3.1.8.5.1.5 - Geochemical Cycles of Basaltic Volcanic Fields. A paper was published in the Journal of Geophysical Research on the terminal stage of basaltic volcanism of the Mauna Kea shield volcano (Frey et al, 1990). These basalts are remarkably similar in mineralogy and geochemistry to the Quaternary basalt of the Yucca Mountain region. The model developed for the fractionation and ascent history of Mauna Kea basalt is similar to the model developed for the Quaternary basalt of the Yucca Mountain region.

2.2.6.9 Study 8.3.1.8.5.2 - Characterization of Igneous Intrusive Features

Scoping work to support preparation of Study Plan 8.3.1.8.5.2 continued.

2.2.6.10 Study 8.3.1.8.5.3 - Investigation of Folds in Miocene and Younger Rocks of the Region

No progress was made in this study during the reporting period. This is an out-year study.

2.2.7 Human Interference (SCP Section 8.3.1.9)

2.2.7.1 Study 8.3.1.9.1.1 - An Evaluation of Natural Processes that Could Affect the Long-Term Survivability of the Surface Marker System at Yucca Mountain

No progress was made in this study during the reporting period. This is an out-year study.

2.2.7.2 Study 8.3.1.9.2.1 - Natural Resource Assessment of Yucca Mountain

Study Plan 8.3.1.9.2.1 was completed and went through formal USGS review; the study plan was transmitted to the Project Office on July 13, 1990.

Activity 8.3.1.9.2.1.2 - Geophysical Assessment of Mineral Resources. Project staff presented a summary of major geophysical results to the NAS/National Research Council panel at the University of Hawaii on July 26 and 27, and participated in a Swedish Exchange program during the period August 23 through September 1, 1990. Lists of all gravity and magnetic computer programs being used by the Project were prepared as a major step toward QA implementation.

2.2.7.3 Study 8.3.1.9.2.2 - Water Resource Assessment of Yucca Mountain

The study plan is currently in revision following receipt of Project Office comments.

2.2.7.4 Study 8.3.1.9.3.1 - Evaluation of Data Needed to Support an Assessment of the Likelihood of Future Inadvertent Human Intrusion

No progress was made in this study during the reporting period. This is an out-year study.

2.2.7.5 Study 8.3.1.9.3.2 - An Evaluation of the Potential Effects of Exploration for, or Extraction of, Natural Resources on the Hydrologic Characteristics at Yucca Mountain

No progress was made in this study during the reporting period. This is an out-year study.

2.2.8 Meteorology (SCP Section 8.3.1.12)

2.2.8.1 Study 8.3.1.12.1.1 - Characterization of the Regional Meteorological Conditions

Compilation of regional meteorological data is ongoing.

2.2.8.2 Study 8.3.1.12.1.2 - Plan for Synthesis of Yucca Mountain Project Meteorological Monitoring

The plan for the synthesis of meteorological monitoring data has been incorporated into the Meteorological Monitoring Plan, Revision 2 (draft).

2.2.8.3 Study 8.3.1.12.2.1 - Meteorological Data Collection at the Yucca Mountain Site

The revised Meteorological Monitoring Plan was submitted to the Project Office on September 10, 1990. The revised plan was submitted for review as a study plan on September 28, 1990.

Activity 8.3.1.12.2.1.1 - Site Meteorological Monitoring Program. Meteorological monitoring at the NTS in support of site characterization is ongoing.

2.2.8.4 Study 8.3.1.12.4.1 - Characterize the Potential Extreme Weather Phenomena and their Recurrence Intervals

No progress was made in this study during the reporting period. This is an out-year study.

2.2.9 Offsite Installations and Operations (SCP 8.3.1.13)

No progress was made in this activity due to budgetary constraints.

2.2.10 Surface Characteristics (SCP Section 8.3.1.14)

2.2.10.1 Investigation 8.3.1.14.1 - Studies to Provide the Topographic Characteristics of Potential Locations of Surface Facilities

Work continued in processing and construction of orthophotographic perspectives of the proposed site facilities.

2.2.10.2 Study 8.3.1.14.2.1 - Exploration Program

Activity 8.3.1.14.2.1.1 - Site Reconnaissance. The SNL "Study Plan for Exploration and Field Testing of Soil and Rock Properties Near the Prospective Surface Facilities," by J. D. Gibson and S. Young, entered the review process.

Activity 8.3.1.14.2.1.2 - Preliminary Exploration. No progress during the reporting period.

Activity 8.3.1.14.2.1.3 - Detailed Exploration. No progress during the reporting period.

2.2.10.3 Study 8.3.1.14.2.2 - Laboratory Tests and Material Property Measurements

Activity 8.3.1.14.2.2.1 - Physical Property and Index Laboratory Tests. No progress during the reporting period due to budgetary constraints.

Activity 8.3.1.14.2.2.2 - Mechanical and Dynamic Laboratory Property Tests. No progress during the reporting period due to budgetary constraints.

2.2.10.4 Study 8.3.1.14.2.3 - Field Tests and Characterization Measurements

Activity 8.3.1.14.2.3.1 - Physical Property Field Tests and Characterization. No progress during the reporting period.

Activity 8.3.1.14.2.3.2 - Mechanical Property Field Tests. No progress during the reporting period.

Activity 8.3.1.14.2.3.3 - Geophysical Field Measurements. No progress during the reporting period.

2.2.11 Thermal and Mechanical Rock Properties (SCP Section 8.3.1.15)

2.2.11.1 Study 8.3.1.15.1.1 - Laboratory Thermal Properties

The study plan for "Laboratory Thermal Properties" was revised to incorporate resolutions of DOE/HQ and Project Office comments that were agreed upon during the comment resolution meeting in December 1989. The revised study plan was returned to the Project Office in March 1990. The plan is currently being examined by the Project Office and DOE/HQ to verify resolution of comments prior to submission to the NRC.

Delays in the schedule of this activity occurred as a result of delays in the systematic drilling program schedule. Site characterization testing cannot proceed until site-specific samples can be collected.

Activity 8.3.1.15.1.1.1 - Density and Porosity Characterization. Procedure development work continued for this activity. The applicability of existing procedures for obtaining grain density is being examined, particularly in terms of gas versus water pycnometer measurements, optimal sample size, and optimal techniques for obtaining measurements on zeolitic samples. Revised technical procedures will be written upon completion of these tests.

Draft procedures were written to govern calibration and testing requirements. These procedures are in various stages of review. Some scoping tests were performed to evaluate the accuracy and precision of test techniques for grain density measurements, with emphasis on definition of optimal sample size.

Activity 8.3.1.15.1.1.2 - Volumetric Heat Capacity Characterization. Draft procedures were written to govern calibration and testing requirements. These procedures are in various stages of review. Some scoping tests were performed to evaluate the accuracy and precision of the test technique (adiabatic pulse calorimetry).

The contractor for thermal-properties measurement established a calibration recall system which is now in operation. High-purity copper shot was obtained for use as a calibration-check standard for specific-heat measurements.

Activity 8.3.1.15.1.1.3 - Thermal Conductivity Characterization. "The Thermal Conductivity of the Topopah Spring Member at Yucca Mountain, Nevada" (Nimick, 1990) was published. This report provides recommended values for rock-mass thermal conductivity of the two units that comprise the welded, devitrified portion of the Topopah Spring Member.

Draft procedures were written to govern calibration and testing requirements, and are in various stages of review. Scoping tests were performed to evaluate the accuracy and precision of test techniques (guarded heat-flow-meter and thermal comparator).

The contractor for thermal-properties measurement established a calibration recall system which is now in operation. Multiple samples of two standard materials (Pyroceram and Pyrex) were obtained for use as calibration and calibration-check standards.

2.2.11.2 Study 8.3.1.15.1.2 - Laboratory Thermal Expansion Testing

The study plan for "Laboratory Thermal Expansion Testing" was revised to incorporate resolutions to DOE/HQ and Project Office comments that were agreed upon during the comment resolution meeting in August 1989. The revised study plan was returned to the Project Office in November 1989. The plan was submitted to DOE/HQ in September 1990 for submission to the NRC.

Delays in the schedule of this activity occurred as a result of delays in the overall project schedule. Site characterization testing cannot proceed until site-specific samples can be collected.

Activity 8.3.1.15.1.2.1 - Thermal Expansion Characterization. Draft procedures were written which govern calibration requirements for this activity; these procedures are in various stages of review. A procedure to govern thermal-expansion testing is being written. Several scoping tests will be conducted to evaluate the accuracy and precision of the test technique (pushrod dilatometry).

The contractor for thermal-expansion measurements established a calibration-recall system which is now in operation. Calibration standards traceable to the NIST were obtained for use in calibration and calibration checks for the dilatometer.

2.2.11.3 Study 8.3.1.15.1.3 - Laboratory Determination of Mechanical Properties of Intact Rock

Technical review of Study Plan 8.3.1.15.1.3 was completed by the Project Office and DOE/HQ personnel last year. The plan was revised in response to comments from regulatory and QA reviewers from the Project Office and was resubmitted to the Project Office on November 30, 1989. It should be submitted for NRC review in the near future.

Delays in the schedule of this activity occurred as a result of delays in surface-based drilling and construction of the ESF. Site characterization testing cannot proceed until site-specific samples can be collected.

Activity 8.3.1.15.1.3.1 - Compressive Mechanical Properties of Intact Rock at Baseline Experiment Conditions. Prototype laboratory mechanical experiments for strength and elastic properties continued to be run to prepare the technical procedures necessary for future testing at baseline conditions.

Baseline conditions are defined as saturated samples tested at room temperature and atmospheric pressure and $10^{-5}s^{-1}$ axial strain rate.

Activity 8.3.1.15.1.3.2 - Effects of Variable Environmental Conditions on Mechanical Properties. Prototype laboratory experiments were run and technical procedures were completed in preparation for running a series of low strain rate and creep experiments to study the time-dependent deformation of the welded tuff in the repository horizon (thermal/mechanical stratigraphic unit TSw2). Temperature also will be varied from 22°C to 250°C to accentuate any possible thermal effects.

A report entitled "Tensile Strength Testing of Topopah Spring Tuff" (Teufel and McNamee) remained at the Project Office for review.

An abstract entitled "Mechanical Anisotropy of the Yucca Mountain Tuffs" (Price et al.) was submitted to the 1991 International Topical Meeting on High Level Radioactive Waste Management.

2.2.11.4 Study 8.3.1.15.1.4 - Laboratory Determination of Mechanical Properties of Fractures

The study plan for "Laboratory Determination of the Mechanical Properties of Fractures" (Price et al.) continued in SNL review and should be submitted for SNL internal review soon.

Delays in the schedule of this activity occurred as a result of delays in surface-based drilling and construction of the ESF. Site characterization testing cannot proceed until site-specific samples can be collected.

Activity 8.3.1.15.1.4.1 - Mechanical Properties of Fractures at Baseline Experiment Conditions. A laser profilometer is being developed and tested. This tool will aid in the characterization of natural and artificially produced fractures. The profiles from a large data base of natural fractures will be compared to the artificial fracture profiles. These data then can be used to extrapolate in situ conditions from laboratory mechanical test results.

Activity 8.3.15.1.4.2 - Effects of Variable Environmental Conditions on Mechanical Properties of Fractures. Prototype experiments continued to obtain results from rotary shear and triaxial compression tests on samples under the same environmental conditions. These tests will be used to determine the behavior of fractures under a variety of conditions.

The techniques for describing the profile of a fracture and a discussion of the relationship between roughness and other properties were in "Surface Roughness and the Physical Properties of Fractures," and presented by S. R. Brown at the 31st U.S. Symposium on Rock Mechanics, June 1990, Golden, Colorado.

"Scale Effects in the Shear Behavior of Joints in Welded Tuff" (Blejwas and Hansen) and "The Effects of Shear and Normal Stress Paths on Rock Friction" (Olsson) were presented at Rock Joints, A Conference of the International Society for Rock Mechanics, June 1990, Loen, Norway.

2.2.11.5 Study 8.3.1.15.1.5 - Excavation Investigations

The preparedness review for Work Plan 1.2.4.2.1.1.1 has been nearly completed. The work encompassed by this plan cannot be conducted until the ESF is constructed. The work in the ESF will be controlled by Study Plan 8.3.1.15.1.5.

Activity 8.3.1.15.1.5.1 - Shaft Convergence. No progress during the reporting period. Prototype testing activities were delayed due to the closure of G-Tunnel.

Activity 8.3.1.15.1.5.2 - Demonstration Breakout Rooms. No progress during the reporting period. Prototype testing activities were delayed due to the closure of G-Tunnel.

Activity 8.3.1.15.1.5.3 - Sequential Drift Mining. No progress during the reporting period. Prototype testing activities were delayed due to the closure of G-Tunnel.

2.2.11.6 Study 8.3.1.15.1.6 - In Situ Thermomechanical Properties

Work Plan 1.2.4.2.1.1.2, "In Situ Thermomechanical Properties," by F. D. Hansen, was completed and issued as a controlled document. The plan includes five major thermomechanical experiments to be conducted in the ESF. The preparedness review for Work Plan 1.2.4.2.1.1.2 has been nearly completed. The work encompassed by this plan cannot be conducted until the ESF is constructed. The work in the ESF will be controlled by Study Plan 8.3.1.15.1.6.

Activity 8.3.1.15.1.6.1 - Heater Experiment in Unit TSw1. Reported under Study 8.3.1.15.1.6.

Activity 8.3.1.15.1.6.2 - Canister-Scale Heater Experiment. Reported under Study 8.3.1.15.1.6.

Activity 8.3.1.15.1.6.3 - Yucca Mountain Heated Block. Reported under Study 8.3.1.15.1.6.

Activity 8.3.1.15.1.6.4 - Thermal Stress Measurement. Reported under Study 8.3.1.15.1.6.

Activity 8.3.1.15.1.6.5 - Heated Room Experiment. Reported under Study 8.3.1.15.1.6.

2.2.11.7 Study 8.3.1.15.1.7 - In Situ Mechanical Properties

Work Plan 1.2.4.2.1.1.3, "In Situ Mechanical Properties" by F. D. Hansen, was completed and issued as a controlled document. The plan includes the rock mass response experiments and the plate loading tests to be conducted in the ESF and certain accesses. The preparedness review has been nearly completed. The work in this plan cannot start until the underground excavations are well advanced. The feasibility of deployment of the plate loading test outside the

ESF depends upon the repository/ESF configuration. This work will be controlled by Study Plan 8.3.1.15.1.7.

Activity 8.3.1.15.1.7.1 - Plate Loading Tests. Reported under Study 8.3.1.15.1.7.

Activity 8.3.1.15.1.7.2 - Rock-Mass Strength Experiment. Reported under Study 8.3.1.15.1.7.

2.2.11.8 Study 8.3.1.15.1.8 - In Situ Design Verification

Study Plan 8.3.1.15.1.8, "In Situ Design Verification," was submitted to the Project Office for review.

Work Plan 1.2.4.2.1.1.4, "In Situ Design Verification," was completed and issued as a controlled document. The preparedness review has been nearly completed. The work in this plan cannot start until the underground excavations are well advanced. This work will be controlled by Study Plan 8.3.1.15.1.8.

The paper "Prototype Testing for In Situ Geomechanical Investigations at Yucca Mountain" (Luke and Finley, 1990) was presented at the International Topical Meeting on High Level Radioactive Waste Management, Las Vegas, Nevada, and published in the conference proceedings.

Activity 8.3.1.15.1.8.1 - Evaluation of Mining Methods. No progress during the reporting period. Prototype testing activities were delayed due to the closure of G-Tunnel.

Activity 8.3.1.15.1.8.2 - Monitoring of Ground-Support Systems. No progress during the reporting period. Prototype testing activities were delayed due to the closure of G-Tunnel.

Activity 8.3.1.15.1.8.3 - Monitoring Drift Stability. No progress during the reporting period. Prototype testing activities were delayed due to the closure of G-Tunnel.

Activity 8.3.1.15.1.8.4 - Air Quality and Ventilation Experiments. No progress during the reporting period. Prototype testing activities were delayed due to the closure of G-Tunnel.

2.2.11.9 Study 8.3.1.15.2.1 - Characterization of the Site Ambient Stress Conditions

Activity 8.3.1.15.2.1.1 - Anelastic Strain Recovery Experiments in Core Holes. No progress during the reporting period due to budgetary constraints.

Activity 8.3.1.15.2.1.2 - Over-Core Stress Experiments in the Exploratory Shaft Facility. Laboratory tests for ultrasonic velocities, water content, bulk density, and unconfined compressive strength of tuff samples from the Grouse Canyon Member were completed. Interpretation of borehole dilatometer tests and borehole-camera fracture logs is continuing. A report describing

field procedures and test results is underway; included in the report are laboratory results and analysis.

A study was made of microfractures observed in oriented thin sections in the welded tuff of the Grouse Canyon member. Several stages of hydrous iron, manganese, titanium, and rare-earth minerals followed by adularia (a potassium feldspar) were found to line the microfractures. At present, microfracture orientations appear to be randomly distributed, but this may be due to a small sample size. These results were presented in a poster, entitled "Fracture Studies in the Welded Grouse Canyon Tuff: Laser Drift of the G-Tunnel Underground Facility, Rainier Mesa, Nevada Test Site, Nevada" (Diehl et al.) on September 13-14, 1990, at the USGS-CASY symposium on "Fractures, Hydrology, and Yucca Mountain."

Configuration Identification Request Forms (CIRFs) were submitted and baselined for USBM-PC and BHFRAC. Both programs are written for IBM-compatible microcomputers. USBM-PC reduces data from the U.S. Bureau of Mines borehole deformation gage to determine the three-dimensional stress regime in a rock mass, and BHFRAC calculates the strike and dip of structures encountered in a borehole from depth-and-angle measurements. Both programs were classified as existing, data reduction, and ancillary. Additional required documentation provided for each program are a Software Verification Report, source code listing, Software Summary Form, and Software Application Description.

2.2.11.10 Study 8.3.1.15.2.2 - Characterization of the Site Ambient Thermal Conditions

Scoping work continued in support of the preparation of Study Plan 8.3.1.15.2.2.

Activity 8.3.1.15.2.2 - Characterization of the Site Ambient Thermal Conditions. A temperature log was obtained in test well UE-25p#1, six years after the previous log and seven years after completion of the well.

USGS staff served on the steering committee for the Southern Basin and Range Transect (SOBART), which should provide opportunities for research complementary to the projects. Staff also provided input to resolving problems in implementing the QA Program. Thermistor calibration facilities, the thermal conductivity apparatus, and the digital data acquisition system in the Geothermal Studies logging truck have all been redesigned, reconfigured, and updated.

2.2.12 Preclosure Hydrology (SCP Section 8.3.1.16)

2.2.12.1 Study 8.3.1.16.1.1 - Characterization of Flood Potential of the Yucca Mountain Site

A comment resolution meeting following DOE review of Study Plan 8.3.1.16.1.1 was held, and the review comments were satisfactorily resolved. The retyped plan was then resubmitted for final DOE approval on April 27,

1990. Audit review and Project Office approval were completed in September 1990. The study plan was submitted to DOE/HQ for transmittal to NRC.

Activity 8.3.1.16.1.1.1 - Site Flood and Debris Hazards Studies. Intensive rainfall and subsequent runoff occurred throughout southern Nevada during the summer of 1990 (June to September). Localized flooding was noticeably greater than it had been for half a decade. Storms occurred more frequently over a broad area than during any summer since 1984. Runoff results were reconnoitered and documented as part of this activity to the degree that time and manpower would allow. As is common during summers in the Great Basin and Mojave Desert areas, the intense rainfall was geographically spotty throughout the region, and total rainfall varied greatly from place to place during individual storms, as well as cumulatively at specific sites during the summer flood season.

Reviews continued of the available literature on flooding and debris hazards in arid environments.

2.2.12.2 Study 8.3.1.16.2.1 - Location of Adequate Water Supply for Construction, Operation, Closure and Decommissioning of a Mined Geologic Disposal System at Yucca Mountain

Revision continues on Study Plan 8.3.1.16.2.1.

2.2.12.3 Study 8.3.1.16.3.1 - Determination of the Preclosure Hydrologic Conditions of the Unsaturated Zone at Yucca Mountain

No progress was made in this study during the reporting period. This is an out-year study.

2.2.13 Preclosure Tectonics (SCP Section 8.3.1.17)

2.2.13.1 Study 8.3.1.17.1.1 - Potential for Ash Fall at the Site

This study was inactive during the reporting period.

2.2.13.2 Study 8.3.1.17.2.1 - Faulting Potential at the Repository

Activity 8.3.1.17.2.1.1 - Assess the Potential for Surface Faulting at Prospective Sites of Surface Facilities Important to Safety. No progress during the reporting period due to budgetary constraints.

Activity 8.3.1.17.2.1.2 - Assess the Potential for Displacement on Faults That Intersect Underground Facilities. No progress during the reporting period due to budgetary constraints.

2.2.13.3 Study 8.3.1.17.3.1 - Relevant Earthquake Sources

Study Plan 8.3.1.17.3.1 was completed and reviewed and was transmitted to the Project Office on August 1, 1990.

2.2.13.4 Study 8.3.1.17.3.2 - Underground Nuclear Explosion Sources

Activity 8.3.1.17.3.2.1 - Determine the Range of UNE Sources. No progress during the reporting period.

Activity 8.3.1.17.3.2.2 - Determine Maximum Underground Nuclear Explosion Sources. No progress during the reporting period.

2.2.13.5 Study 8.3.1.17.3.3 - Ground Motion From Regional Earthquakes and Underground Nuclear Explosions

Activity 8.3.1.17.3.3.2 - Select or Develop Empirical Models for Ground Motion From Underground Nuclear Explosions. The study plan entitled "Development of Empirical Models of Underground Nuclear Explosions" (Phillips and Walck) was completed and submitted to the Project Office in September 1990.

Several QA surveillances on various aspects of the weapons test seismic program have resulted in modifications to each of the technical and experimental procedures governing the work in this technical area.

Data were collected from the UNE BULLION conducted in mid-June 1990.

"Prediction of Pseudo-Relative Velocity Response Spectra at Yucca Mountain for Underground Nuclear Explosions" (Walck and Phillips) was submitted to the Project Office for policy review. An abstract of "The Weapons Test Seismic Investigation Program at Yucca Mountain" (Phillips et al.) was submitted to the International Topical Meeting on High Level Radioactive Waste Management.

The paper "Exploratory Shaft Seismic Design Basis Working Group Report" (Subramanian et al., 1990) was published as a SAND report in August.

2.2.13.6 Study 8.3.1.17.3.4 - Effects of Local Site Geology on Surface and Subsurface Motions

Study Plan 8.3.1.17.3.4 was completed and reviewed; the study plan was transmitted to the Project Office on July 6, 1990.

Activity 8.3.1.17.3.4.1 - Determine Site Effects From Ground Motion Recordings. No progress during the reporting period.

Activity 8.3.1.17.3.4.2 - Model Site Effects Using the Wave Properties of the Local Geology. A paper entitled "Selected Characteristics of Seismicity in the Southern Great Basin of Nevada-California" (Rogers et al.) was revised. The paper has been accepted for publication in a USGS Bulletin.

Work has been in progress to revise and obtain approval for Study Plan 8.3.1.17.3.4. A CIRF has been filed for the existing software that will be used to correct and analyze the digital seismic data needed for site response studies. Work has also been in progress to bring these programs back on line and adapt them to this study. Planning has been conducted to deploy the newly arrived portable digital seismographs in the Yucca Mountain-Jackass Flats area during the winter of 1990-91. A scientific notebook plan has been written to cover this work.

2.2.13.7 Study 8.3.1.17.3.5 - Ground Motion at the Site from Controlling Seismic Events

Study Plan 8.3.1.17.3.5 was completed and is being revised by the author following formal USGS internal review.

Activity 8.3.1.17.3.5.1 - Identify Controlling Seismic Events. No progress during the reporting period.

Activity 8.3.1.17.3.5.2 - Characterize Ground Motion From the Controlling Seismic Events. No progress during the reporting period.

2.2.13.8 Study 8.3.1.17.3.6 - Probabilistic Seismic Hazards Analyses

Continued preparation of Study Plan 8.3.1.17.3.6.

Activity 8.3.1.17.3.6.1 - Evaluate Earthquake Sources. No progress during the reporting period due to budgetary constraints.

Activity 8.3.1.17.3.6.2 - Evaluate Ground Motion Probabilities. No progress during the reporting period due to budgetary constraints.

2.2.13.9 Study 8.3.1.17.4.1 - Historical and Current Seismicity

The DOE review was completed of Study Plan 8.3.1.17.4.1. Comment resolution was completed. The study plan was revised in response to comment resolution and was transmitted to the Project Office on July 6, 1990.

Activity 8.3.1.17.4.1.1 - Compile Historical Earthquake Record. All data have been analyzed to present. The seismicity report for 1987-1989 is in preparation.

Activity 8.3.1.17.4.1.2 - Monitor Current Seismicity. The following papers were submitted or are in preparation for publication: (1) "Seismicity, Strain, and Detection/Location Threshold in the Southern Great Basin, Nevada" (Gomberg), manuscript in preparation; (2) "There is Nothing Better than Good S: The Effect of S-Wave Arrival Times on the Accuracy of Hypocenter Estimation" (Gomberg et al.), Bulletin of the Seismological Society of America, submitted for publication; (3) "Seismic Network Configuration, Earthquake Hypocenter Determination; A Reevaluation and New Approaches to Old Problems" (Gomberg), submitted as a chapter in a USGS Bulletin; (4) "Catalog of Seismicity from the SGBSN from 1987-1989" (Harmsen), in review; (5)

"Selected Characteristics of Seismicity in the Southern Great Basin of Nevada and California" (Rogers et al.), submitted as a chapter in a USGS Bulletin; (6) "The Seismicity of Nevada and Some Adjacent Parts of the Great Basin" (Rogers et al.), in Neotectonics of North America (Slemmons, Engdahl, Blackwell, and Schwartz, eds.), GSA Special Paper CSMV-1, submitted for publication.

A poster presentation, written report on Southern Great Basin Seismic Network (SGBSN) status, and oral presentation were made at the USGS-NRC-DOE Regional Seismic Network Review, Reston, Virginia, August 20, 1990. An oral presentation "Regional Seismicity and Tectonic Implications" (Gomberg) was made to the Panel on Coupled Processes, Board on Radioactive Waste Management, National Research Council, Honolulu, Hawaii, July 26-27, 1990. A poster "Fracture Influence on Seismic Velocities, Rainier Mesa to Yucca Mountain" (Harmsen) was presented at the USGS-CASY Symposium "Fractures, Hydrology, and Yucca Mountain," Golden, Colorado, September 13-14, 1990. Oral presentations on status of SGBSN were made at the Monthly Technical Project Officer's Meeting, Las Vegas, Nevada, June 29, 1990,

A scientific notebook plan on two-dimensional seismic array measurements at Yucca Mountain was submitted for final QA approval in August 1990. Technical procedures on the operation and calibration of a remote telemetered seismic array were completed and became effective July 26, 1990.

Sixteen CIRFs (QA documents for software) used for processing seismic network data were completed and submitted to the Software Configuration Management Librarian for baselining on August 30, 1990.

A USGS-CASY poster session on apparent shallow crustal anisotropy determined from nuclear test P-wave residuals is nearly complete. Project members also participated in a USGS-CASY Symposium on September 13-14, 1990, conducted preliminary field work to site new seismic stations, and continued procurement and other work related to upgrading the seismic network.

2.2.13.10 Study 8.3.1.17.4.2 - Location and Recency of Faulting Near Prospective Surface Facilities

An SNL surveillance [D. Gibson (observer), C. McKee (MACTEC, team leader), L. Shephard (technical member, Geomatrix consultant)] was performed on Geomatrix in San Francisco, California, on April 19 and 20, 1990. A work authorization for non-surface-disturbing work was issued to SNL by DOE. Comments and questions by NRC concerning this study plan were received by DOE. Responses are currently under development.

The paper "Synthesis of Studies for the Potential of Fault Rupture at the Proposed Surface Facilities, Yucca Mountain, Nevada" (Gibson et al., 1990) was presented at the International Topical Meeting on High Level Radioactive Waste Management, Las Vegas, Nevada, and published in the conference proceedings.

Deviation reports by SNL to Geomatrix and SNL resulting from the SNL surveillance of Geomatrix on April 19 and 20, 1990, have been resolved.

D. Gibson presented a talk at the NRC/DOE Technical Exchange on "tectonically significant" faults and addressed NRC comments on the Midway Valley Study Plan in Las Vegas, Nevada, and at Exile Hill, NTS, Nevada, on June 12 and 13, 1990.

Activity 8.3.1.17.4.2.1 - Identify Appropriate Trench Locations in Midway Valley. Non-surface-disturbing mapping activities in the Midway Valley study area are continuing.

EP-0001 Rev. B, "Geologic Surface Mapping Near the Prospective Surface Facilities," by J. D. Gibson, F. H. Swan, and J. R. Wesling was issued with an effective date of August 6, 1990.

A summary of existing data for Midway Valley (SAND90-2491) entitled "Compilation and Evaluation of Existing Geologic Data for Midway Valley," by J. R. Wesling and F. H. Swan, is currently in SNL internal review.

Activity 8.3.1.17.4.2.2 - Conduct Exploratory Trenching in Midway Valley. EP-0039 Rev. 00, "Geologic Trench Mapping and Sample Collection Near the Prospective Surface Facilities," by J. D. Gibson, F. H. Swan, and J. R. Wesling is currently in SNL internal review. This EP will govern initial SNL surface-disturbing work in Midway Valley.

In preparation for surface-disturbing activities being initiated in January 1991, SNL personnel have continued their support of the Project Office efforts to complete the job package for this activity.

2.2.13.11 Study 8.3.1.17.4.3 - Quaternary Faulting within 100 km of Yucca Mountain, including the Walker Lane

Technical sections of Study Plan 8.3.1.17.4.3 were mostly completed. Work is continuing on programmatic sections at present.

Activity 8.3.1.17.4.3.1 - Conduct and Evaluate Deep Geophysical Surveys in an East-West Transect Crossing the Furnace Creek Fault Zone, Yucca Mountain, and the Walker Lane. The results of field testing and processing of seismic reflection data acquired near Beatty, Nevada, and along line AV-1 in the eastern Amargosa Desert, completed as a feasibility study, were recently published by Brocher et al. (1990). A paper was prepared for the Journal of Geophysical Research, which provides a comparison of Vibroseis and explosive source methods for deep crustal seismic reflection profiling in the Basin and Range Province. The data on which this analysis is based are described in the Brocher et al. (1990) paper. The seismic reflection data and analysis of these data, as presented in this paper, indicate that, in the vicinity of Yucca Mountain, explosive source methods will provide a better means of profiling the lower crust (below 4 s two-way travel time) than the Vibroseis method. The advantage of explosive methods is that the signal levels are higher, and thus processing of the resulting data is more robust and convincing.

Staff presented a poster entitled "Mapping the Base of the Tertiary Basin Fill Aquifer by Seismic Reflection Profiling" (Brocher) at the USGS-CASY symposium on Fractures and Hydrology at Yucca Mountain held in Denver on

September 13-14, 1990. The poster presented a geological interpretation of line AV-1 comparing differing geophysical estimates to the base of the Tertiary basin fill as well as the results of synthetic reflection profiles across Crater Flat and Yucca Mountain. Beneath the western end of Crater Flat, the base of the Tertiary basin fill is expected to occur at 2 to 3 s two-way travel time, whereas beneath Yucca Mountain, this reflection may occur between 1 and 1.5 s.

USGS staff participated in a peer review of seismic methods held by DOE in Las Vegas on September 10-12. Preparation for the meeting included completing the analysis and interpretation of seismic line AV-1, as well as the forward modeling of synthetic reflection data across Crater Flat and Yucca Mountain, based on published cross sections of these regions. Preparation also included writing a statement of objectives and an informal proposal, as well as a meeting with the Panel Chairman in June to discuss plans for the Peer Review Panel meeting.

Geoelectric work during this report period consisted of (1) reviewing previous deep-penetrating, regional magnetotelluric (MT) surveys and some deep controlled source surveys; and (2) work on documentation related to QA requirements necessary to back up the finalization of a data report for MT field experiment in 1986. Work also entailed the preparation of software documentation and related revision of the MT technical procedure. The primary accomplishment was organization and submittal of four MT software product CIRFs, which collectively entail about 15 modules.

Manuscripts on remote sensing and on geoelectric techniques were submitted as chapters for the report "Status of Geophysical Studies in the Yucca Mountain Area."

Activity 8.3.1.17.4.3.2 - Evaluate Quaternary Faults within 100 km of Yucca Mountain. The interpretation of Quaternary lineaments and faults from aerial photographs and published mapping was completed for the eastern parts of the Saline Valley and Darwin Hills 1:100,000 quadrangles, Nevada and California. The maps and accompanying report have been through USGS review as of August 1990. Two reports on interpretation of Quaternary lineaments and faults are in preparation.

Project staff completed preliminary aspects of anticipated future studies of known and suspected Quaternary faults in the Ash Meadows and Amargosa Valley areas of the Amargosa Desert. The distribution, orientation, age, and kinematic significance of these faults are, for the most part, poorly known. Studies are in progress to better define the distribution and orientations of these features, which will help determine the methods and scope of studies needed to evaluate their age and kinematic significance. Progress made during this reporting period consisted principally of completion of index maps at 1:24,000 and 1:100,000 scale for compilation of 1,526 low-sun-angle aerial photographs of the Amargosa Desert region, 1:12,000 scale, which were flown for the University of Nevada/Reno, in 1988. These photos provide nearly complete large-scale airphoto coverage of the entire Amargosa Desert. In addition, a pilot photogeologic study of the Ash Meadows area, which comprises about four 1:24,000 scale quadrangles of the Amargosa Desert region, was approximately 50 percent completed.

Activity 8.3.1.17.4.3.5 - Evaluate Structural Domains and Characterize the Yucca Mountain Region with Respect to Regional Patterns of Faults and Fractures. The following remote sensing materials and data sets currently available were evaluated and determined to be highly suitable for interpretative investigations of the Yucca Mountain region:

- Complete coverage of all spectral bands of Multi-Spectral Scanner (MSS) coverage of the entire region, suitable for concatenation, spectral band ratioing, and discrimination of iron-oxide surface materials at scales of 1:500,000 with clear detail, and at 1:250,000 at the margin of good resolution.

- Thematic Mapper (TM) coverage of the entire region, with spatial resolution at two times that of the MSS coverage (hence well-suited for geologic mapping and fracture pattern investigations, as well as spectral discrimination of desert varnish surfaces).

- TM coverage of the Beatty 1:100,000 quadrangle has been computer processed, enhanced, and geodetically fit to a USGS 1:100,000-scale base map. The resulting color infrared composite is planned for publication as a USGS Miscellaneous Map. Interpretations of fracture patterns are underway.

- Flightline synthetic aperture radar (SAR) data tapes for all four 2-degree 1:250,000 quadrangles (Caliente, Las Vegas, Death Valley, and Goldfield) were processed. SAR mosaics are available for the Las Vegas quadrangle, and can be concatenated for the Caliente quadrangle. The mosaics are now available for the Death Valley and Goldfield quadrangles. The mosaics are fitted to USGS map bases at 1:250,000 and are of high clarity; they are of exceptional value in geomorphic and structural mapping. Although slant-to-ground range corrections have been made, radar shadow and layover problems remain in areas of high relief. Scale corrections are underway to prepare the mosaics for fracture pattern analysis at 1:100,000 for the Beatty quadrangle.

The Software CIRF for the REMAPP software package was completed and submitted; this software is for the purpose of processing LANDSAT, MMS, and TMS imagery.

2.2.13.12 Study 8.3.1.17.4.4 Quaternary Faulting Proximal to the Site within Northeast-Trending Fault Zones

Started preparation of Study Plan 8.3.1.17.4.4.

Activity 8.3.1.17.4.4.1 - Evaluate the Rock Valley Fault System. Progress on this activity included (1) work on the left-lateral fault study plan, (2) examination of aerial photographs of the Cane Wash area for evidence of young faulting, (3) continued compilation of the strip map along the Rock Valley fault, (4) initiation of compilation of shallow seismic refraction data collected in 1984, (5) completion of the field review of trench logs for Trench 14, and (6) initiation of work on an index map of shallow seismic investigation locations.

2.2.13.13 Study 8.3.1.17.4.5 - Detachment Faults at or Proximal to Yucca Mountain

Study Plan 8.3.1.17.4.5 was reviewed by the USGS, revised, and transmitted to the Project Office on May 1, 1990.

Activity 8.3.1.17.4.5.2 - Evaluate Postulated Detachment Faults in the Beatty-Bare Mountain Area. A detailed geologic map (1:24,000 scale) of the Bare Mountain area, with cross-sections, was transmitted for DOE approval. The map depicts several important structural features within the geologic setting of Yucca Mountain, including the Fluorspar Canyon, Bare Mountain, Meikeljohn Peak, and Tungsten Canyon faults.

A geologic map was published (Maldonado and Hausback, 1990) that shows detachment faults, upper-plate normal faults, and stratigraphy of the northeast part of the Bullfrog Hills. An interpretative paper of this work also was published (Maldonado, 1990) that discusses an extremely distended terrane containing two detachment faults and an overlying complex of normal faults. The detachment faults define three structurally discordant plates. The lower detachment fault separates a lower plate of metamorphosed Late Proterozoic rocks from an overlying middle plate, composed of slivers of lower and middle Paleozoic clastic and carbonate rocks. The middle-plate rocks are brecciated and essentially unmetamorphosed, and highly attenuated. The upper detachment fault separates the middle-plate rocks from an upper-plate succession of block-faulted Miocene volcanic, volcaniclastic, and sedimentary rocks. Attenuation of the Late Proterozoic and Paleozoic strata indicates large movement on the detachment faults; the upper plate has been extended more than 100 percent and possibly more than 275 percent locally. The geometry of the normal faults and the repetition and dip direction of the Miocene rocks indicate that major extension, at least of the upper plate, was west-northwest-east-southeast and occurred mostly between about 10 and 8 Ma.

2.2.13.14 Study 8.3.1.17.4.6 - Quaternary Faulting within the Site Area

The staff responded to DOE verification review of Study Plan 8.3.1.17.4.6 and continued preparing responses to DOE comments.

Activity 8.3.1.17.4.6.1 - Evaluate Quaternary Geology and Potential Quaternary Faults at Yucca Mountain. USGS staff field-checked earlier work done on the Bow Ridge fault; this included checking of trench wall maps of Trench 14. The results of the Trench 14 work are being prepared for publication as a USGS Bulletin (Taylor).

Photogeologic reinterpretations were made of previously mapped (Swadley and Carr, 1987) faulted surfaces along the Windy Wash fault system and the logs of three trenches were reevaluated.

Staff completed a photogeologic study of faults and lineaments compiling a 1:24,000 map, based on 1:6,000 low-sun vertical aerial photography.

Development of a digitized geologic data base of the Yucca Mountain area with on-line map production capability is underway. During this period, faults and geologic contacts of the bedrock geologic map (Scott and Bonk,

1984) were digitized. Cartographic systems to display and differentiate between various classes of Quaternary and older faults were demonstrated. Data on the Quaternary faults, geologic units, and trench locations from Swadley et al. (1984) were digitized and merged with the bedrock data. The map and data base will facilitate planned compilation, mapping, and trench investigations of Quaternary faults at Yucca Mountain.

Mineral separations and purification of carbonate samples collected from Crater Flat, Busted Butte, and the Amargosa Desert were continued. Water samples collected from test well UE-25p#1 and travertine and calcite vein samples collected in the Amargosa Desert/Ash Meadows area for uranium-series dating were analyzed.

Revisions also were completed of geochemical procedures for uranium-series dating, uranium-trend dating, and spike calibration for uranium-series and uranium-trend analyses.

A paper on uranium-series dating of secondary carbonates near Yucca Mountain was published during the reporting period (Muhs et al., 1990). The following paper was revised and accepted during the reporting period: Muhs, D.R., "The Last Interglacial/Glacial Transition in North America: Evidence from Uranium-Series Dating of Coastal Deposits," in Clark, P., and Lea, P., eds., The Last Interglaciation/Glaciation Transition in North America: GSA Special Paper, in press. [This paper was not the result of investigations at Yucca Mountain, but is relevant because it tests the suitability of rhizoliths for uranium-series dating which have been used for dating at Yucca Mountain.] Another paper titled "^{238}U-^{234}U-^{230}Th Systematics and the Origin of Near-Surface Secondary Carbonates in the Yucca Mountain Area" was revised for inclusion in a USGS Bulletin.

Project staff attended the High Level Radioactive Waste Management conference in Las Vegas, Nevada, April 9-12, 1990; a paper was presented at this conference entitled "Uranium-Series Dating of Secondary Carbonates near Yucca Mountain, Nevada: Applications to Tectonic, Paleoclimatic and Paleohydrologic Problems" (Muhs et al.).

Staff also attended the USGS-CASY colloquium on volcanic hazards assessment at Yucca Mountain in April, and informally reviewed a report by J. S. Szymanski of DOE on the interpretation of isotopic data associated with the Yucca Mountain area.

2.2.13.15 Study 8.3.1.17.4.7 - Subsurface Geometry and Concealed Extensions of Quaternary Faults at Yucca Mountain

Preparation of Study Plan 8.3.1.17.4.7 continued.

Activity 8.3.1.17.4.7.1 - Evaluate Intermediate Depth (2 to 3 km) Reflection and Refraction Methods and the Planned Potential Application of these Methods within the Site Area. A paper is being prepared (Brocher et al.) for the GSA Bulletin concerning seismic reflection evidence for Tertiary detachment faulting in the eastern Amargosa Desert. This paper provides an interpretation of line AV-1, based on outcrops, shallow well control, and coincident geophysical surveys.

Seismic refraction work during this period consisted of data analysis and synthesis; no new field work was undertaken. The primary data base that has been analyzed consists of five seismic refraction profiles that cover the Yucca Mountain area, and one seismic reflection profile that is coincident with one of the seismic refraction profiles in the Amargosa Desert. Potential field and borehole data form important complementary data bases. Of particular interest has been the investigation of the relationship of the seismic structure to (1) regional structure, particularly, high-angle and possible detachment (low-angle) faults; and (2) the identification of structures that might represent aquitards, aquifers, or tectonic hazards.

USGS staff made oral presentations on the tectonics program and supportive geophysical studies for Yucca Mountain at the NAS meeting on Tectonics, Geophysics, and Volcanism held in Honolulu on July 26-27. Staff also attended the following meetings: (1) June 5, Menlo Park, DOE/SAIC/New England Geophysical/USGS planning meeting for the Seismic Peer Review of future seismic work at Yucca Mountain; (2) September 11-12, Las Vegas, DOE Seismic Peer Review meeting to review plans for future seismic work; (3) September 13-14, Denver, USGS-CASY workshop on "Fractures, Hydrology, and Yucca Mountain"; a poster presentation on "Seismic Surveys at Yucca Mountain: Relevance to Fractures and Hydrology" (Mooney).

The staff were involved in QA-related activities. Considerable effort was devoted to the development of new technical procedures, as well as the updating of older procedures, related to seismic surveys and the calibration of seismic instrumentation. Software QA documentation was also developed. The relevant programs include data playback and display, seismic data manipulation and filtering, and seismic velocity and interface depth calculation programs. These programs have been converted from older DEC machines to newer, more reliable IBM-PC compatible computers. Several USGS Open-File Reports documenting the software have been completed.

Progress on the Teleseismic Tomography Interpretive Report has been significant. The manuscript is now about 75 percent complete and will be finished in FY 91.

Activity 8.3.1.17.4.7.2 - Detailed Gravity Survey of the Site Area. A section was prepared on a gravity profile and interpretation for inclusion in the report titled "Feasibility Study of the Seismic Reflection Method in the Amargosa Desert, Nye County, Nevada," USGS Open-File Report 89-133 (Brocher et al., 1990).

A report has been prepared entitled "New Bouguer and Isostatic Residual Gravity Maps of the Nevada Test Site, Nevada and Their Structural and Hydrologic Applications" (Ponce and Oliver), which is intended for release as a USGS Bulletin.

Activity 8.3.1.17.4.7.3 - Detailed Aeromagnetic Survey of the Site Area. The following two draft reports have been prepared for release as USGS Bulletins: (1) "Magnetic Investigations of the Location and Volume of Buried Basalt Near Yucca Mountain, Southwestern Nevada" (Langenheim et al.), and (2) "Status of Aeromagnetic Coverage of Southwestern Nevada and Southeastern California" (R. Sikor et al).

Activity 8.3.1.17.4.7.5 - Evaluate Surface Geoelectric Methods and Plan Potential Applications of these Methods within the Site Area. The main effort has been to organize the available geoelectric data on Yucca Mountain (a related task on more regional data is reported separately--Activity 8.3.1.17.4.3.1). In the period 1979-1982, there were numerous electrical surveys conducted on Yucca Mountain, which resulted in nine primary data reports. It became evident during a query on one of these reports in 1988 that an overview and a general evaluation of these data were required, which would entail correlation among data sets as well as correlations with geologic and drillhole data. A short synopsis of the results of the 1988 query mentioned above was submitted for publication in March of this year.

From April to the present, work has focused on preparing workable summaries of the data. This has entailed (1) investigating the available records on file; (2) compiling a map of the precise locations of the data; (3) reducing the available interpreted models and related drillhole information to compatible formats for evaluation; (4) preparing comparative cross-sections from near-coincident survey traverses; and (5) evaluation, possibly including some interpretation, of these data. The task remains in progress and is somewhat more complicated than expected because some large and important data sets are not published. The unpublished data include nine dipole-dipole traverses and numerous Schlumberger and MT soundings. The major accomplishment has been to compile on three scales (1:12,000, 1:24,000, and 1:100,000) the locations of the available 46 traverses plus 125 separate soundings from 10 different types of electrical surveys. This will form the basis for the evaluation report.

It is apparent, as outlined in the report submitted in March, that there are significant and interpretable resistivity contrasts on Yucca Mountain that can be related to the distribution of volcanic units, and perhaps structure. Drillhole logging and core petrophysical data have allowed a preliminary first interpretation of the generalized resistivity structure of Yucca Mountain. Surface electric data may allow the mapping of electrical units in a general sense allowing for uncertainties in modeling; however, the interpretative part of this evaluation has just begun.

2.2.13.16 Study 8.3.1.17.4.8 - Stress Field within and Proximal to the Site Area

Scoping work as the basis for preparation of Study Plan 8.3.1.17.4.8 continued during the reporting period.

2.2.13.17 Study 8.3.1.17.4.9 - Tectonic Geomorphology of the Yucca Mountain Region

The preparation of Study Plan 8.3.1.17.4.9 continued.

2.2.13.18 Study 8.3.1.17.4.10 - Geodetic Leveling

Comments on Study Plan 8.3.1.17.4.10 were received from DOE. Comment resolution was conducted and completed in late September. The study plan was revised and transmitted to the Project Office on September 20, 1990.

Activity 8.3.1.17.4.10.1 - Relevel Base-Station Network, Yucca Mountain and Vicinity. Surveying instrumentation was calibrated in accordance with QA specifications.

Activity 8.3.1.17.4.10.2 - Analyze Existing Releveling Data, Yucca Mountain and Vicinity. Comparisons were made of repeated geodetic leveling surveys, starting in 1907, along U.S. Highway 95 in southern Nevada. The comparisons indicate that this could be a viable technique for evaluating vertical tectonic movements. Results of this comparison are being prepared for publication.

2.2.13.19 Study 8.3.1.17.4.11 - Characterization of Regional Lateral Crustal Movement

No progress was made in this study during the reporting period. This is an out-year study.

2.2.13.20 Study 8.3.1.17.4.12 - Tectonic Models and Synthesis

Started preparation of Study Plan 8.3.1.17.4.12 after technical exchanges with DOE and NRC.

Activity 8.3.1.17.4.12.1 - Evaluate Tectonic Processes and Tectonic Stability at the Site. Geologic cross-sections through the Funeral Mountains were completed and transmitted to DOE for concurrence. The cross-sections augment a previously transmitted geologic map of the Funeral Mountains. The map and cross-sections summarize the results of three decades of research in this area.

A report (Fox et al., 1990) describing the geologic framework and Cenozoic evolution of the Yucca Mountain area was presented at the International Symposium on Unique Underground Structures, Denver, Colorado, in June 1990. The report notes that volcanic and volcaniclastic rocks composing Yucca Mountain consist of a 1- to 3-km thick stratiform sequence of Miocene ash-flow and interbedded tuffs erupted mainly from the Timber Mountain-Claim Canyon-Oasis Valley areas. These volcanic rocks ponded over sedimentary rocks of probably late Oligocene to Miocene age, whose lateral equivalents are exposed to the west (Grapevine Mountains), south (Bat Mountain area), and east (Red Mountain area). The sedimentary rocks, consisting of fluvial and lacustrine deposits, interfinger with fanglomerate shed from uplands to the west and south, and overlie a basement of structurally imbricated Paleozoic and late Proterozoic clastic and carbonate strata. The report further states that the proposed repository would be excavated from a non-lithophysal zone within the lower part of the Paintbrush Tuff, a widespread unit within the Miocene tuffs composing Yucca Mountain. Revised estimates of the thickness of this non-lithophysal zone indicate that the lower, down-dip extremity of the

planned repository could be raised 130 m, thus reducing the grade within the repository and increasing the distance to the water table below. Because of closely spaced fracturing and low in situ stresses within the repository block, lateral support of fractured rocks is likely to be poor.

USGS staff attended and provided technical support for numerous meetings during the reporting period, including meetings with the Project Office, the NRC, the State of Nevada, NWTRB, and the NAS.

2.3 REPOSITORY OVERVIEW

2.3.1 Geomechanical Analyses (SCP Section 8.3.2.1.4.1)

The SNL Software Quality Assurance Implementing Procedure (QAIP 3-2) became effective July 20, 1990. Until that date, no quality-affecting code development or analysis was permitted. Thus, much of the work of this task was limited to planning and scoping work relative to code and model development, and maintenance of existing software.

Work continued on the JAC-implemented compliant-joint model. Recent efforts have been directed toward coupling the shear and normal compliance descriptions of joint deformation. Efforts to complete the documentation for JAC-3D, a three-dimensional, finite-element code using the conjugate gradient technique, continued. Scoping analyses to verify and check out the code are being formulated.

UDEC, a two-dimensional, discrete-element code, was recently acquired and updated. It is now up and running on the SNL computer system. Scoping and planning analyses, using UDEC and JAC-2D (using slide lines) of the slot tests, are being performed to assist in preliminary evaluation of the tests. The slide line capability in JAC-2D is being developed to consider Mohr-Coulomb slip behavior. Addition of a displacement-discontinuity capability in the boundary element code HEFF is being evaluated. This capability would allow for evaluation of potential localized shear displacements.

Documentation for the code SPECTROM-31 remained in peer review. Documentation for the codes JEM, SPECTROM-41, and SPECTROM-349 is being revised following peer review.

Addition of a displacement-discontinuity capability in the boundary element code HEFF is being evaluated. This capability would allow for evaluation of potential localized shear displacements.

The papers "Yucca Mountain Project Thermal and Mechanical Codes, First Benchmark Exercise. Part I: Thermal Analysis" (Costin and Bauer, 1990) and "YMP Thermal and Mechanical Codes, First Benchmark Exercise. Part II: Elastic Analysis" (Bauer and Costin, 1990) were published as SAND reports. The paper "Application of Models for Jointed Rock to the Analysis of Prototype Testing for the Yucca Mountain Project" (Costin, 1990) was presented at the 31st U.S. Rock Mechanics Symposium, Golden, Colorado, and published in the symposium proceedings.

2.3.2 Seismic Analyses (SCP Section 8.3.2.1.4.2)

No progress during the reporting period.

2.3.3 Ventilation Analyses (SCP Section 8.3.2.1.4.3)

No progress during the reporting period.

2.3.4 Safety Analyses (Section 8.3.2.1.4.4)

No progress during the reporting period.

2.4 REPOSITORY DESIGN

2.4.1 Configuration of Underground Facilities (Postclosure) (SCP Section 8.3.2.2

2.4.1.1 Design Activity 1.11.1.1 - Compile a Comprehensive List of All the Information Required From Site Characterization to Resolve this Issue

No progress during the reporting period.

2.4.1.2 Design Activity 1.11.1.2 - Determine Adequacy of Existing Site Data

No progress during the reporting period.

2.4.1.3 Design Activity 1.11.1.3 - Document Reference Three-Dimensional Thermal/Mechanical Stratigraphy of Yucca Mountain

No progress during the reporting period.

2.4.1.4 Design Activity 1.11.1.4 - Preparation of Reference Properties for the Reference Information Base

No progress during the reporting period.

2.4.1.5 Design Activity 1.11.2.1 - Compile Waste Package Information Needed for Repository Design

No progress during the reporting period.

2.4.1.6 Design Activity 1.11.3.1 - Area Needed Determination

Results from a study on area requirements are being incorporated into a report entitled "Underground Area Requirements for a Proposed Nuclear Waste Repository at Yucca Mountain" (Hertel et al.). This report will present a

general approach to area estimation, as well as numerical examples comparing the area requirements for two waste receipt schedules (oldest fuel first and levelized), a 2010 emplacement start date, and three design-basis areal power densities (APDs): 57, 80, and 100 kW/acre.

2.4.1.7 Design Activity 1.11.3.2 - Usable Area and Flexibility Evaluation

No progress during the reporting period. Resources diverted to support the ESF Alternatives Study.

2.4.1.8 Design Activity 1.11.3.3 - Vertical and Horizontal Emplacement Orientation

No progress during the reporting period. Resources diverted to support the ESF Alternatives Study.

2.4.1.9 Design Activity 1.11.3.4 - Drainage and Moisture Control Plan

No progress during the reporting period.

2.4.1.10 Design Activity 1.11.3.5 - Criteria for Contingency Plan

No progress during the reporting period.

2.4.1.11 Design Activity 1.11.4.1 - Chemical Changes Resulting from the Use of Construction Materials

No progress during the reporting period.

2.4.1.12 Design Activity 1.11.4.2 - Material Inventory Criteria

No progress during the reporting period.

2.4.1.13 Design Activity 1.11.4.3 - Water Management Criteria

"Evaluation of Potential Impact of Moisture on an Emplacement Drift Environment in an Underground Repository" (O'Leary and McPherson) completed SNL internal technical review and is currently being prepared for SNL management review. This paper presents the results of a study examining the moisture pick-up capabilities of leakage ventilation in emplacement drifts.

2.4.1.14 Design Activity 1.11.5.1 - Excavation Methods Criteria

No progress during the reporting period.

2.4.1.15 Design Activity 1.11.5.2 - Long-Term Subsidence Control Strategy

No progress during the reporting period.

2.4.1.16 Design Activity 1.11.6.1 - Thermal Loading for Underground Facility

Project Office comments on "Determination of Equivalent Thermal Loading as a Function of Waste Age and Burnup" (Mansure and Petney) were received. These comments were addressed and the proposed resolutions transmitted for Project Office approval. This report presents a method of scaling the emplacement densities of wastes with different burnup rates and ages, so that the repository-scale thermomechanical effects are equivalent to those calculated for a baseline case.

"Areal Power Density: A Preliminary Examination of Underground Heat Transfer in a Yucca Mountain Repository and Recommendations for Thermal Design Approaches" (Hertel and Ryder) completed SNL internal technical and management reviews and was transmitted to the Project Office for policy review.

2.4.1.17 Design Activity 1.11.6.2 - Borehole Spacing Strategy

No progress during the reporting period.

2.4.1.18 Design Activity 1.11.6.3 - Sensitivity Studies

Project Office comments on "A Thermomechanical Far-Field Model of Yucca Mountain" (Brandshaug) and "A Sensitivity Study of the Thermomechanical Far-Field Model of Yucca Mountain" (Brandshaug) were received and incorporated. The proposed resolutions were transmitted to the Project Office.

2.4.1.19 Design Activity 1.11.6.4 - Strategy for Containment Enhancement

No progress during the reporting period.

2.4.1.20 Design Activity 1.11.6.5 - Reference Calculations

No progress during the reporting period.

2.4.1.21 Design Activity 1.11.7.1 - Reference Postclosure Repository Design

No progress during the reporting period.

2.4.1.22 Design Activity 1.11.7.2 - Documentation of Compliance

No progress during the reporting period.

2.4.2 Repository Design Criteria for Radiological Safety (SCP Section 8.3.2.3)

2.4.2.1 Design Activity 2.7.1.1 - Design Evaluation for Compliance With Radiological Safety Design Criteria and Performance Goals

No progress during the reporting period.

2.4.3 Nonradiological Health and Safety (SCP Section 8.3.2.4)

2.4.3.1 Design Activity, SCP Section 8.3.2.4.1.1 - Design Activity to Verify Access and Drift Usability

This work is directed toward performance of analyses and experiments which will be used to facilitate an understanding of rock mass behavior. Due to software QA concerns, analyses have been limited to planning and scoping work.

The paper "Preliminary Methodology for Design of Stable Drifts for the Yucca Mountain Project" (Bauer et al., 1990) was presented at the International Topical Meeting on High Level Radioactive Waste Management, Las Vegas, Nevada, and published in the conference proceedings.

Preliminary laboratory results, which will be used to support the laboratory large block tests, were developed, reviewed, and implemented under the Experiment Procedure entitled "Development of Procedures for Large Block Tests and Evaluation of Analysis Techniques."

Tentative selection of a brick material was made and its elastic properties determined. Surface preparation of brick sides and measurement of the normal and shear behavior of these surfaces is being studied. SNL staff visited the Waterways Experiment Station and reviewed work in progress. Conduct of joint normal and shear tests was observed. A double-bladed cut-off saw is being designed and constructed to aid in preparation of blocks, and the anvil design for the large block test is being conceptualized.

Two avenues of approach are being taken to attempt to begin to understand the potential effects of repository thermal loading upon fault movement. In the first, STRES3D analyses, which used the SCP-CDR time-sequenced repository thermal loading, are being studied. The stress state along the location of the surface of major faults and the change in the stress state resulting from repository thermal loading is being evaluated. In the second set of analyses, a two-dimensional, finite-element model using the JAC-2D code has been assembled. The model contains the major normal faults in the vicinity of the repository block. The faults are modeled to sole out above the carbonate basement in the area. A slide line algorithm is being used to model the faults. Preliminary results on both sets of analyses are forthcoming.

In support of the G-Tunnel mining evaluations experiment, analyses using both elastic- and compliant-joint material models are being completed. This work will be documented in a SAND report.

The paper "G-Tunnel Welded Tuff Mining Experiment Data Summary" (Zimmerman et al., 1990) was published as a SAND report in April.

2.4.3.2 Design Activity, SCP Section 8.3.2.4.1.2 - Design Activity to Verify Air Quality and Ventilation

No progress during the reporting period.

2.4.4 Preclosure Design and Technical Feasibility (SCP Section 8.3.2.5)

2.4.4.1 Design Activity 4.4.3.1 - Operations Plan to Accompany the Advanced Conceptual Design

No progress during the reporting period. Resources diverted to support the ESF Alternatives Study.

2.4.4.2 Design Activity 4.4.3.2 - Operations Plan to Accompany the License Application Design

No progress during the reporting period. Resources diverted to support the ESF Alternatives Study.

2.4.4.3 Design Activity 4.4.4.1 - Repository Design Requirements for License Application Design

Revision D-Final of the "Repository Design Requirements for the Yucca Mountain Mined Geologic Disposal System" (RDR), SAND85-0260 (Stevens, 1990), was completed and submitted to the Project Office in April 1990. This revision was in response to the Project Office review. A consistency check for flowdown of requirements from the System Requirements document, dated April 2, 1990, was performed informally. The check indicated that the requirements flow down in a general way, but often not verbatim. An informal consistency check for compatibility and consistency between the RDR and other requirements documents (ESF Subsystem Design Requirements Document (SDRD) Waste Package Design Requirements) likewise show inconsistencies in format and content.

On September 11, 1990, direction was received from the Project Office to suspend work temporarily on the RDR, except for those interface components necessary to support the ESF Alternatives Study. These interface requirements will be incorporated as part of the ESF Alternatives Study documentation.

2.5 SEALS SYSTEM DESIGN

2.5.1 Shaft and Borehole Seals Characteristics (SCP Section 8.3.3.2)

2.5.1.1 Study 1.12.2.1 - Seal Material Properties Development

Activity 1.12.2.1.1 - Detailed Property Determination of Cementitious-Based and Earthen Materials. No progress during the reporting period.

Activity 1.12.2.1.2 - Hydraulic Conductivity and Consolidation Testing of Crushed Tuff. No progress during the reporting period.

2.5.1.2 Design Activity 1.12.2.2 - A Degradation Model for Cementitious Materials Emplaced in a Tuffaceous Environment

Data from Problem Definition Memo 76-5, "Analysis (using EQ3NR/EQ6) of the Geochemical Effects of Cementitious Materials on Ground Water and Tuff in the MPZ and at the Base of the Shaft," have been analyzed to determine volumetric changes accompanying the reaction of cements and J-13 ground water. These volume changes are explained by a few reactions of cementitious materials and water. Secondary reactions are predominantly important at the beginning of each run when quantities and volumetric changes are small.

"Estimation of Geochemical Behavior of Concretes Placed at Yucca Mountain" (Hinkebein and Gardiner) has been prepared and submitted to the 1991 International Topical Meeting on High Level Radioactive Waste Management. This paper reports on the interaction of three different concrete formulations with J-13 water. Changes to the total water chemistry, as well as mineralogical changes in the concrete, are discussed. The effect of these changes on porosity and permeability of the concrete are estimated. "Modeling Geochemical Stability of Cement Formulations for Use as Shaft Liner and Sealing Components at Yucca Mountain" (Gardiner and Hinkebein) was prepared for the 1990 MRS Meeting.

2.5.1.3 Study 1.12.2.3 - In Situ Testing of Seal Components

No progress during this reporting period.

2.5.1.4 Design Activity 1.12.4.1 - Development of the Advanced Conceptual Design (ACD) for Sealing

Design Subactivity 1.12.4.1.1 - Define Subsystem Design Requirements. A second draft of an International Atomic Energy Agency (IAEA) publication, "Performance of Engineered Barriers in Deep Geological Repositories," was prepared at SNL and is undergoing review by the co-authors.

"Preliminary Laboratory Testing of Selected Cementitious Material for the Yucca Mountain Project Repository Sealing Program" (Licastro et al., 1990) was presented at the International Topical Meeting on High Level Radioactive Waste Management, Las Vegas, Nevada, and published in the conference proceedings.

Progress was made on scoping calculations to determine flow in fractures subject to matrix imbibition. These calculations, which allow a comparison between water entry into shafts and water entry into ramps, support the ESF alternative studies, the SDRD performance studies, and the sealing material degradation model.

The total fracture infiltration and the water penetration distance were also calculated. These quantities were computed as a function of the initial saturation of the Tiva Canyon Member, the fracture aperture, the number of fractures per meter, and time.

Performance discriminators for the ESF Alternatives Study were developed. Proximity to major features is not a discriminator from the standpoint of performance, but characterization of these features is essential to the validation of models and hence essential to the understanding of repository flow processes. Ramps are considered slightly superior to shafts because water entry into, and drainage from, ramps occurs off the repository block. It was also concluded that the number and size of openings into the repository block are not performance discriminators within the framework of the proposed options. An analysis was initiated to define the flow of water into shafts and ramps through faulted/fractured regions.

Influence diagrams and key parameters were developed as part of the ESF Alternatives Study for both the performance assessment and the site characterization and testing groups. These key parameters will be used to facilitate the scoring of options. Also, the proposed locations of shafts and ramps were plotted on a topographic map. The drainage areas associated with each shaft and ramp entry and the peak discharge and the height of flow in the ephemeral stream were computed.

A review continued of the performance implications of the ESF Title II, first design package. The first design package consists of borrow pit, topsoil storage area, and the Drill Hole Wash Road. It was determined that the topsoil storage area was sufficiently removed from the repository block to have no performance impacts. The borrow pit, however, was located in Drill Hole Wash at the northeast boundary of Yucca Mountain. This feature was to be constructed by removing up to 10 feet of alluvium from the wash. Because experiments performed by the USGS in adjacent Pagany Wash suggest that alluvium in washes may retard infiltration, constructing the borrow pit within or very near the repository boundary may cause increased infiltration within the repository block. Watering the Drill Hole Wash Road to control dust remains an open issue pending the completion of calculations by SNL.

Performance measures for drifting in the Calico Hills were developed by SNL to assist the SAIC team in evaluating strategies. A model was developed with very limited applicability; the sole purpose was to allow an estimation of the performance impacts of drifting. The added flux caused by drifting through the Calico Hills was the measure of performance used. The increase in flux through the Calico Hills was measured by the volume of drifting divided by the volume of undisturbed Calico Hills using the following assumptions:

1. Flow in the undisturbed CHn is independent of flow in the drift. The drift area as modeled may be artificially increased to allow confidence in the assumption of independence of flow columns.

2. The pressure changes across the undisturbed rock column and the rock column containing the drift are identical.

3. A constant hydraulic gradient (not necessarily unity) exists in the undisturbed CHn column, and a possibly different yet consistent hydraulic gradient occurs in the disturbed column.

4. The hydraulic conductivity of the drifts is conservatively assumed to be infinite.

Design Subactivity 1.12.4.1.2 - Perform Trade-Off Studies to Support Advanced Conceptual Design Development. A trip to the White River Shale Oil Project (WRSOP) was conducted to observe effectiveness of the fracture grouting program. Because the mine penetrated the Birds Nest aquifer, grouting to control water inflow was necessary. The water inflow (after grouting) from two areas was 1-3 gallons per minute (gpm). SNL staff reviewed detailed notes taken during the development of the mine. Emphasis focused on the effectiveness of the grouting operation.

Computer code (SHAFT.SEAL) analyses were completed for two categories (open borehole with casing and open borehole without casing). The calculations to mitigate selected processes and events for a sealed borehole were defined. These calculations involved superposition of several loads for selected environmental conditions. The performance of borehole seals was estimated.

Work commenced to develop a table that classifies boreholes and sealing issues (shallow versus deep) by covering the diversity of problems. This table will identify individual boreholes and indicate whether the boreholes are shallow or deep. It will indicate which formations they penetrate and are collared in, their proximity to faults, if they penetrate fault planes above or below the repository, and their proximity to alluvial recharge areas and potential susceptibility to perched water. Additional maps were identified and will also be developed for summarizing the information. A second table will be prepared summarizing each potential scenario, the number of existing and proposed boreholes affected, and their absolute and relative significance to these issues.

Other efforts included developing a technical approach for calculating standoff distance from an exploratory borehole, developing a map based upon flow net analyses that could account for anisotropic distribution of fractures, and defining the significance of boreholes around the repository boundaries.

During August 1990, a major status and planning exercise was undertaken for the completion of performance calculations on Design Investigation Memo 239, Development of a Strategy to Seal Exploratory Boreholes.

Project staff attended a course on the "Fundamentals of Grouting" sponsored by the University of Missouri/Rolla in Denver, Colorado, on April 30 through May 4, 1990.

Design Subactivity 1.12.4.1.3 - Develop Advanced Conceptual Design for Seals. No progress during the reporting period.

2.5.1.5 Design Activity 1.12.4.2 - Development of the License Application Design for Sealing

Design Subactivity 1.12.4.2.1 - Define Subsystem Design Requirements. No progress during the reporting period.

Design Subactivity 1.12.4.2.2 - Perform Trade-Off Studies to Support License Application Design Development. No progress during the reporting period.

Design Subactivity 1.12.4.2.3 - Develop License Application Design for Seals. No progress during the reporting period.

2.6 WASTE PACKAGE DESIGN AND PERFORMANCE ASSESSMENT

2.6.1 Postemplacement Near-Field Environment (SCP Section 8.3.4.2)

2.6.1.1 Design Activity 1.10.1.1 - Consideration of 10 CFR Part 60.135 (a) Factors

No activity specifically in this design activity was done during the reporting period. The information needed is being developed in other activities. Information on the interactions of the waste package and its emplacement environment is being developed in Information Need 1.10.4. Considerations listed in 10 CFR 60.135 (a) are being considered in Performance Issues 1.4 (Section 2.6.3) and 1.5 (Section 2.6.2) and in the Design Issue 2.6 (Section 2.6.3).

2.6.1.2 Study 1.10.4.1 - Characterize Chemical and Mineralogical Changes in the Postemplacement Environment

Revision of the Geochemistry Study Plan (8.3.4.2.4.1) continued. Revisions will address review comments and bring the study plan into compliance with the QA requirements.

An outline was developed and completed for the Preliminary Waste Package Environment Report.

The following Technical Implementing Procedures (TIPs) have been approved and will soon be distributed:

TIP-YM-4 - Preparation of Standards for the Determination of Trace Elements in J-13 Well Water by ICP-OES
TIP-YM-7 - Operation of the Jarrel Ash 975 Atom Comp ICP-OES
TIP-NF-16 - Prepare Core Wafer Samples
TIP-NF-17 - Carbonate Analysis with the OIC Model 524D Carbon Analyzer
TIP-NF-18 - Testing Rock-Water Interactions Using a Rocking Autoclave

TIP-NF-14 - "Preparation of Crushed Rock Samples" is being reviewed.

Activity 1.10.4.1.1 - Rock-Water Interactions at Elevated Temperatures. Work was completed on comment resolution activities for the paper by A. Meike

and W. Glassley entitled "In Situ Observation of the Alpha/Beta Cristobalite Transition Using High Voltage Electron Microscopy."

Discussions were held with LANL in May and July on mineral stability work and plans as part of the integration of geochemical activities.

Provided input to a working meeting on volcanic scenarios, emphasizing geochemical concerns.

Activity 1.10.4.1.2 - Effect of Grout, Concrete, and Other Repository Materials on Water Composition. A draft Study Plan for Activities 1.10.4.1.2 and .6, "Characterization of the Effects of Man-Made Materials on Chemical and Mineralized Changes in the Post Emplacement Environment," was completed and is undergoing internal review.

Activity 1.10.4.1.3 - Composition of Vadose Water from the Waste Package Environment. Consideration and planning of natural analogue site work continued.

Activity 1.10.4.1.4 - Dissolution of Phases in the Waste Package Environment. Dissolution and precipitation kinetics experiments of both kaolinite and gibbsite at 80°C were completed. The experiments progressed normally.

Study of the dissolution and precipitation kinetics of cristobalite at 200°C is in progress.

The Activity Plan for "Single Phase Dissolution Experiments" was completed in draft form and submitted for internal review.

Activity 1.10.4.1.5 - Effects of Radiation on Water Chemistry. No data are available at this time. When data become available, this activity will be initiated.

Activity 1.10.4.1.6 - Effects of Container and Borehole Liner Corrosion Products on Water Chemistry. Described in Activity 1.10.4.1.2 above.

Activity 1.10.4.1.7 - Numerical Analysis and Modeling of Rock-Water Interaction. An abstract by C. Bruton entitled "Geochemical Modeling of Water/Clinoptilolite Interactions" was prepared for submission to the GSA October 1990 Meeting.

2.6.1.3 Study 1.10.4.2 - Hydrologic Properties of Waste Package Environment

Activity 1.10.4.2.1 - Single-Phase Fluid System Properties. Most of the Lawrence Livermore National Laboratory (LLNL) hydrology work in this period was in the two-phase fluid system properties activity.

Activity 1.10.4.2.2 - Two-Phase Fluid System Properties. Work continued on the fracture healing experiment of the Topopah Spring Tuff sample to investigate the effect of temperature on the permeability of a fractured sample to water with the pore water standing still during heating. Permeability was measured before and after the sample was heated. The effect

on fracture healing of steam flowing through the sample was also investigated. By comparing the permeability to gas before and after steam flows through the sample, the effect of steam on fracture healing can be determined. Comments from the technical reviewers are now being incorporated into the paper entitled "Laboratory Investigation of Fracture Healing" (Lin).

Work is continuing on the G-Tunnel tuff suction potential experiments. The humidity chamber was shut down for repairs for several months. The repairs have been completed, and testing of the chamber is now proceeding. Monitoring continued of the three-dimensional imbibition of water into G-Tunnel tuff samples as a function of time. Imbibition of moisture in a 100% relative humidity environment is very different from that in liquid water.

Text revisions are being made to the paper entitled "In Situ Changes in the Moisture Content of Heated Welded Tuff Based on Thermal Neutron Measurements" (Ramirez et al.).

Work continued on the refinements to the long-range plan for hydrology, on activity plans, and on the draft for the Preliminary Near-Field Environment Report.

LLNL staff continued to work on incorporating the changes to the Hydrology Study Plan.

A response was made to the State of California on their comments on the SCP (CA comment #23) regarding the air gap.

Final review comments were incorporated into the paper entitled "Temperature Measurements for the Engineered Barrier System Field Test" (Lin et al.), and it was submitted to the Project Office for approval.

The Pacific Northwest Laboratory (PNL) Preliminary Report on Postclosure Risk Assessment was re-reviewed by LLNL staff.

A response to the Project Office review comments was submitted for the paper by D. Wilder entitled "Engineered Barrier Systems and Canister Orientation Studies for the Yucca Mountain Project, Nevada."

A proposal was received from the University of Nevada/Reno entitled "Characterization of Thermally-Induced Water/Vapor/Gas Transport in the Rock Mass" by P. Mousset-Jones for review and possible funding. A response was sent to the Project Office for comment.

Dr. G. Danko of the University of Nevada-Reno proposed work on a Heat-Pipe Concept. This request was passed on to the Project Office.

LLNL staff gave a presentation on April 10 to NRC staff members and staff from CNWRA on the hydrology work being done in the Near-Field Environment technical area. A tour of the laboratory in Building 243 was given, along with an overview of the Near-Field Environment technical area.

A paper entitled "Role of Water in Fractured Healing of Topopah Spring Tuff" was presented by W. Lin at the AGU Spring meeting May 29-June 1.

A paper entitled "Modeling Unsaturated Hydrothermal Flow in the Near-Field Environment" was presented by T. Buscheck and J. Nitao to the second meeting of the UZ Hydrology Peer Review Team in Las Vegas, June 6, 1990.

A paper entitled "Engineered Barrier Systems and Canister Orientation Studies for the Yucca Mountain Project, Nevada" was presented by D. Wilder at the International Symposium for Unique Underground Structures in Denver, June 11-13.

A paper entitled "Hydrologic Impacts on Waste Isolation at Yucca Mountain Prospective Repository Nevada" was presented by D. Wilder to the U.S./USSR Joint Conference on Environmental Hydrology and Hydrogeology in Leningrad, June 18-22, and in Budapest, Hungary, June 25-29.

A poster paper entitled "Laboratory Investigations on Fracture Healing" was presented by W. Lin at the SEG Workshop in Denver on August 6-8, 1990.

LLNL participated in a joint meeting on September 12-13 to discuss coordination of SNL/LLNL field and laboratory studies for mechanical attributes.

Activity 1.10.4.2.3 - Numerical Analysis of Flow and Transport in Laboratory Systems. Work will commence when necessary data becomes available from Activity 1.10.4.2.2.

2.6.1.4 Study 1.10.4.3 - Mechanical Attributes of the Waste Package Environment

Activity 1.10.4.3.1 - Waste Package Environment Stress Field Analysis. Project staff continued the revision of the Study Plan for Characterization of Mechanical Attributes of the Waste Package Environment (Study Plan 8.3.4.2.4.3), incorporating the review comments received. The revision includes background research into the effects of temperature and moisture on subcritical crack growth in silicate rocks, the effects of radiation on the thermomechanical properties of rock, the addition of a section describing radiation tests, and applicability and availability of various conceptual and numerical models to this study.

An answer was provided to the NRC on SCA comment #17 regarding radiation effects.

Work continued on Activity Plans for Near-Field tasks.

Draft text was prepared for the Preliminary Near-Field Environment Report.

2.6.1.5 Study 1.10.4.4 - Engineered Barrier System Field Tests

Activity 1.10.4.4.1 - Repository Horizon Near-Field Hydrologic Properties. Close out continued for activities related to the completed experiment in G-Tunnel, including analysis of data and report preparation.

Technical review comments have been incorporated into the final report of the Prototype Test Experiment in G-Tunnel, and the report is being submitted for editing as a formal LLNL report.

Staff completed a technical review of the paper entitled "Temperature Measurements from the Prototype Barrier System Field Test."

The report by A. Ramirez entitled "In Situ Changes in the Moisture Content of Heated Welded Tuff Based on Thermal Neutron Measurements" has been revised, incorporating all technical review comments. It was sent to the Project Office for approval.

A paper by K. Lee entitled "Air Injection Field Measurements to Determine the Effect of a Heat Cycle on the Permeability of Welded Tuff" was sent to the technical reviewers, and a technical review of the paper was completed.

The Memorandum of Understanding (MOU) and the test description for the ESF design were reviewed by D. Wilder and a response was completed for the Input to the Draft ESF Test Descriptions Document.

The review comments for the Scientific Investigation Plan (SIP) for Engineered Barrier System Field Test (EBSFT) were completed and sent to the Project Office.

The EBSFT results were presented by A. Ramirez at the NWTRB meeting held at the NTS on April 6. This included a tour of G-Tunnel. He also gave a presentation on the horizontal prototype test results from G-Tunnel to the International Topical Meeting on High Level Radioactive Waste Management in Las Vegas on April 10.

LLNL staff participated in a meeting on September 24, 1990, with German visitors, and briefed them on Climax test and near-field environment issues.

Activity 1.10.4.4.2 - Repository Horizon Rock-Water Interaction. Samples are not available at this time.

Activity 1.10.4.4.3 - Numerical Analysis of Fluid Flow and Transport in Repository Horizon Near-Field Environment. Code development work on the prototype version of the V-TOUGH code continued with emphasis on pre- and post-processors for three-dimensional modeling. Testing of a two-dimensional "areal" model of the near field around a vertical waste package was also conducted.

The conceptual development of a fracture network model is underway which represents matrix imbibition between fracture junctions through the use of a bulk fracture flow attenuation factor. This model is intended to represent infiltration events in complex fracture networks. In LLNL numerical modeling analyses, the influence of fracture coatings on liquid pulses down fractures is being considered. The effect of channeling on fracture flow, and the effect of vapor flow on the moisture mass balance in Yucca Mountain, are also being considered.

Work continued on the Individual Software Plan for the V-TOUGH code. A preliminary system of configuration management has also been established for the V-TOUGH code.

2.6.2 Characteristics and Behavior of the Waste Form (SCP Section 8.3.5.10)

2.6.2.1 Activity 1.5.1.1 - Integrate Waste Form Data and Waste Package Design Data

Subactivity 1.5.1.1.1 - Integrate Spent Fuel Information. The following procedures have been reviewed, have had review comments resolved, and have been distributed as controlled documents: TIP-YM-2, "Collect, Store, and Distribute Water from Well J-13"; TIP-NF-28, "Solids Analysis: Scanning Electron Microscope"; and TIP-YM-6, "Measurement of the pH of Aqueous Solutions with the Glass Electrode."

The new SIP for waste form testing for spent fuel was approved at LLNL, and comments have been provided by the Project Office. The SIP was written to comply with the existing QA requirements and QA Level assignments of the activities being planned and conducted in the Spent Fuel Waste Form Modeling and Testing technical area. New QA procedures were provided in March 1990 and these are being integrated into a revision of the SIP. Spent fuel waste form data acquisition activities are also being included in this revision.

A "Materials Characterization Center (MCC) Burnup and Fission Gas Release Distribution Workshop" was held June 27-28, 1990, in Seattle. This meeting was attended by both fuel vendor representatives (data suppliers) and repository research representatives (data users). The approach and preliminary results of the Approved Testing Materials (ATM) confirmation work were presented at the meeting. Valuable review and feedback comments were received on the methodology and the need for future ATMs.

Technical activities have continued that are related to ATM confirmation and to the development of results for the burnup and fission gas release distributions of the spent fuel inventory. The issue of controlling proprietary data on fission gas release that may be received from General Electric Company and Westinghouse Electric Company has not been resolved.

Preparation of a draft report on the representativeness of spent fuel ATMs to the total spent fuel inventory was completed at the MCC. The report recommends that at least one (and possibly two) additional fuels should be acquired if the suite of spent fuel testing materials available to the repository project is to be considered representative of the spent fuel inventory. These fuels are a modern high-burning pressurized water reactor (PWR) fuel and a modern high-burnup boiling water reactor (BWR) fuel.

A draft of ORNL/TM-11670, "Distribution of Characteristics of Light Water Reactor Spent Fuel," which was prepared under a subcontract by the managers of the Characteristics Data Base (CDB) at Oak Ridge National Laboratory (ORNL), was received at the MCC and is being reviewed. The report gives background information on the CDB data that were used by the MCC. It also includes additional information on the types and relative quantities of defective and burnable absorber fuel in the spent fuel population. In addition to the MCC

sponsored report, draft report ORNL/TM-11681 entitled "Preliminary Waste Form Characteristics" was received at LLNL to be technically reviewed as part of a cooperative data acquisition activity that was funded from DOE-RW. Data from these reports will be incorporated into the draft Waste Form Characteristics Report.

Subactivity 1.5.1.1.2 - Integrate Glass Waste Form Information. The SIP for the Glass Waste Form Testing was rewritten, reviewed, and is being revised for submission to DOE/HQ. The revision in the SIP concerns QA level assignments. The SIP must conform to new QA guidelines.

2.6.2.2 Activity 1.5.2.1 - Characterization of the Spent Fuel Waste Form

Subactivity 1.5.2.1.1 - Dissolution and Leaching of Spent Fuel. Flow-through dissolution tests on unirradiated UO_2 will measure the rate of dissolution of UO_2 under dynamic, unsaturated conditions measuring a broad range of oxidizing conditions, pH, carbonate/bicarbonate activity, temperature, etc. The results will be combined with results from similar measurements on spent fuel test specimens from the available inventory. From the combined results, a dissolution model can be developed that will describe the dissolution response for a range of water chemistries and for different repository conditions.

To perform the tests, a controlled atmosphere glove box has been acquired at LLNL. An oxygen analyzer has been installed, and tests have just begun to evaluate the atmosphere purification system. Electrical wiring and piping connections have been completed. An activity plan was completed for these tests and submitted for approval.

A presentation entitled "Spent Fuel Leaching: Flow-Through Tests" (Leider) was prepared and given at the NWTRB Meeting in August.

Technique development on the electrochemistry of UO_2 dissolution continued but will probably be discontinued after September due to decreasing funding allocations. A new potentiostat arrived, and the operation of this new instrument was verified by remeasuring the cyclic voltammetry of UO_2 electrodes in 0.5 M $NaSO_4$ solution (pH = 10.5). The IR compensation feature of the instrument was found to perform excellently by measuring the small changes in current due to oxidation and reduction with the large ohmic drop (large background current) due to the impedance of the UO_2 electrode. As previously observed, a change is still measured in voltammograms with number of sweeps. The first scan of the UO_2 electrode always produced a different voltammogram than successive sweeps. After four to five cycles, the voltammogram changed very little. The voltammograms published in the literature correspond to only the first cycle on new electrodes. Additional work is required to interpret the changes in voltammograms.

A photothermal deflection optical technique was set up for potentially measuring concentration gradients near the UO_2 surface during electrochemistry. These gradient deflections can be modeled to identify the mechanisms for surface speciation/reactions during electrochemical cycling.

Some reproducible low noise deflection traces have been measured. This technique may lead to an interpretation that explains the cyclic changes in voltammograms.

A paper by C. Wilson and W. Gray entitled "Effects of Water Composition on the Dissolution of UO_2 under Oxidizing Conditions," vol. 2, pp. 1432-1436, was presented at the International Topical Meeting on High Level Radioactive Waste Management. The paper describes results to date from flow-through tests with UO_2. A presentation entitled "An Overview on Spent Fuel Studies that Support the Yucca Mountain Project" (Wilson) was given at the American Ceramic Society Annual Meeting, April 22-26, 1990, in Dallas, Texas, and a presentation entitled "Spent Fuel Leaching: Hot Cell Tests" (Wilson) was made to the NWTRB in August 1990. The Series 2 (PNL 7169) (Wilson) and Series 3 (PNL 7170) (Wilson) reports were submitted for publication and distribution.

In preparation to do spent fuel testing, flow-through tests on UO_2 were started in de-ionized water (DIW) and dilute $NaHCO_3$ solution to evaluate the effects of argon gas sparging to remove dissolved oxygen from the water. The dissolution rate in the dilute $NaHCO_3$ solution decreased by a factor of about 700 over a few days as a result of argon gas sparging. The dissolution rate in the DIW tests decreased by a factor of 25 as a result of argon gas sparging over the same time period. Dissolution rates in both tests appear to be approaching similar low values near the detection limit for uranium measurements. These preliminary tests confirmed results that suggest the bicarbonate reduces the dissolution rate of UO_2 in oxygen depleted water.

Geometric surface areas were determined for the spent fuel fragments used in the Series 2 and Series 3 Spent Fuel Dissolution Tests. Nominal surface area measurements are required to analytically represent release rate test data of the soluble radionuclides. The area estimate method used involved weighing the fuel particles to determine the distribution of particle weights and calculating geometric surface areas for various representative particle shapes. Geometric surface areas ranged from 2.1 to 2.6 cm^2/g depending on fuel type and particle shape assumptions. An appendix was written to the Series 3 report describing the surface area determinations (PNL-7170).

An abstract for a paper entitled "Results from Long-Term Dissolution Tests Using Oxidized Spent Fuel" (Wilson) was submitted for presentation at the MRS Meeting, November 26-29, 1990, in Boston. The paper will present results through 1,200 days of Cycle 2 for two semi-static dissolution tests with oxidized spent fuel specimens in J-13 well water.

A draft test plan for Series 4 semi-static spent fuel dissolution tests was written. The proposed Series 4 tests will be conducted in a similar manner to the previously completed Series 3 tests. The test matrix includes six spent fuel specimens: a high fission gas release fuel, a BWR fuel, a gadolinia-doped fuel, oxidized fuel, and extended testing of two PWR fuel specimens previously tested in the Series 3 tests. The four new spent fuel specimens are expected to exhibit a range of soluble radionuclide release behavior, and all six specimens are representative of potential fuel states in the repository. Removal of portions of the fuel specimens during Cycle 2 and subsequent test cycles for flow-through testing is also being planned. The flow-through tests will be described in a separate test plan.

A spent fuel workshop was attended in Gull Harbour, Manitoba, Canada, on September 3-5, 1990. The Canadians have performed oxidation testing of spent fuel bundles with defective cladding. Information was exchanged on dissolution studies that use flow-through techniques.

Subactivity 1.5.2.1.2 - Oxidation of Spent Fuel. The thermogravimetric apparatus (TGA) testing was not restarted due to funding reductions.

The dry-bath oxidation tests continued to operate without any problems. The interim weighing examinations were completed on the bimonthly schedule. Plans were made, and six samples were removed for microstructural examination from the dry-baths at the next interim examination.

Optical photographs of spent fuel fragments were analyzed with an image-analyzing computer to relate various measured parameters (such as mean, side length, spherical volume, surface area, three-dimensional aspect ratio, and extensivity) to pyramidal base lengths and pyramid altitude. The growth rate of U_4O_9 along grain boundaries in spent fuel was determined by computer-assisted image measurement of ATM-103 fuel oxidized at 195°C.

The computer-assisted image measurements were made to determine the shapes of spent fuel fragments and to estimate statistical values of two pyramidal volume parameters for oxidation model development. These preliminary measurements indicate that the fuel fragments are primarily wedge shaped volumes. By decomposing the spatial volume of fragments into sets of pyramidal volumes, some progress was made in representing the oxidation response of larger fragments that have a distribution of sizes and shapes. A presentation entitled "Statistical Model for Spent Fuel Oxidation" (Stout) was given at an American Ceramic Society meeting in Dallas, Texas, April 1990. A presentation, "Spent Fuel Oxidation" (Einzinger), was given to the NWTRB in August 1990.

Subactivity 1.5.2.1.3 - Corrosion of Zircaloy. Data were obtained on Spent Fuel hardware characteristics which estimate the amounts, surface areas, and radionuclide inventories of spent fuel hardware components that are part of BWR and PWR assemblies. The hardware materials consist of stainless steel, Inconel, and Zircaloy.

A test plan by L. Bunnell and H. Smith entitled "Pressurized Tube Testing to Determine the Susceptibility of PWR Spent Fuel Cladding to Cracking under Tuff Repository Conditions" was revised based on reviewer comments. The scope was widened to better provide for the repository project data requirements.

A second set of pressurized tube scoping tests with unirradiated Zircaloy cladding was initiated and completed. The tests are designed to check the pressurization system and the method for detecting cracking that penetrates the oxide film. A presentation entitled "Spent Fuel Cladding Degradation" (Smith) was given to the NWTRB in August 1990.

Due to funding reductions, the fluoride/cladding interaction testing and development activities were not supported. The report of earlier work by N. Uziemblo and H. Smith entitled "An Investigation of the Influence of Fluoride on the Corrosion of Zircaloy-4: Initial Report" (PNL-6859) was released for publication and distribution.

Subactivity 1.5.2.1.4 - Corrosion of and Radionuclide Release from Other Materials in the Spent Fuel Waste Form. No significant activities.

Subactivity 1.5.2.1.5 - Evaluation of the Inventory and Release of Carbon-14 from Zircaloy Cladding. A test plan entitled "Thermal Release of Carbon-14 from PWR and BWR Spent Fuel Cladding" was revised and has been approved. This test plan was incorporated into an activity plan for carbon-14 testing. The activity plan is being reviewed for completeness.

A paper by H. Smith and D. Baldwin entitled "An Investigation of Thermal Release of Carbon-14 from PWR Spent Fuel Cladding" has been approved for publication. A data package supporting the work reported in the paper has been prepared.

Brookhaven National Laboratory is nearing completion on its effort to assess the potential release of gaseous $^{14}CO_2$ from small perforations in waste containers as a function of temperature, hole size, open porosity within the hole, and time based on the waste package design parameters and environmental conditions described in the Project SCP.

Subactivity 1.5.2.1.6 - Other Experiments on the Spent Fuel Waste Form. No significant activities.

2.6.2.3 Activity 1.5.2.2 - Characterization of the Glass Waste Form

Subactivity 1.5.2.2.1 - Leach Testing of Glass.

Unsaturated Testing of West Valley Demonstration Project (WVDP) and Defense Waste Processing Facility (DWPF) Glass

The N2 tests (SRL actinide-doped glass) have completed the 234-week (4.5 year) period, and the analyses of cations and radionuclides have been completed. After 4.5 years, the rate of glass reaction appears to be similar to that observed early in the reaction progress.

The N3 tests (ATM-10, a West Valley actinide-doped glass) were sampled in August after 166 weeks. This sampling was done to develop a method of detecting particulate materials that are released from the test and suspended in solution. At the sampling of each test, an aliquot of solution was taken for cation, pH, carbon, anion, and radionuclide analyses. The remaining solution was then filtered through a sequence of filters. These samples are awaiting analysis pending completion of a Readiness Review.

Static Leach Testing of WVDP and DWPF Glass

The Task Plan, "YMP Static Leach Tests," controlling the long-term static leach testing of DWPF glass, has been submitted by Argonne National Laboratory (ANL) to LLNL for action. Three test matrices are identified: (1) simple tests to aid in model development, (2) simple site-relevant tests for model validation, and (3) complete site-relevant tests for model validation.

No further work can be done until the Readiness Review for this activity has been completed. A draft of the activity plan to cover this work has been

completed. (A report covering this work has been published; see Ebert et al., 1990.)

Parametric Studies of WVDP and DWPF Glasses Based on the Unsaturated Test

A topical report discussing all the parametric experiments has been completed. Internal ANL review has been completed, and the revised version will be sent to LLNL for comment. Although not included in the topical report, analyses of reacted glass samples are being performed using an Analytical Electron Microscope (AEM). Sections of the reacted top, bottom, and side surfaces of the glass from experiment P-III-10 were successfully prepared. This sample was exposed to one drop of EJ-13 water every 3.5 days for 52 weeks. The layer consists of a complex structure of overlapping clay layers interspersed between iron-rich backbone structures. This type of structure is similar (although more complex) to the reacted layer structure observed on SRL 165 glass reacted for 280 days in static MCC-1 leach tests. (A report covering this work was published; see Bates and Gerding, 1990.)

Parametric Studies of WVDP and DWPF Glasses

The SVT (product of Time and Surface Area-to-Volume ratio) matrix was performed to determine which surface area to volume (SA/V) ratios should be used for tests performed as part of the static leach of glass activity. The samples from these tests are undergoing detailed characterization, the results of which will be presented in a manuscript entitled "The Effect of SA/V Ratio on the Formation of Secondary Phases during Glass/Water Reactions" (Bates).

Subactivity 1.5.2.2.2 - Materials Interactions Affecting Glass Leaching.

Studies of Glass Surface Layers and Precipitation

A presentation entitled "The Radionuclide Content of Secondary Mineral Phases Formed During Glass Reaction" (Bourcier and Knauss) was made at the American Ceramic Society Meeting in Dallas, Texas, in April. The results of radionuclide analyses of secondary phases were discussed. As mentioned in previous reports, plutonium and americium were primarily retained in the reaction layer in the steam-reacted samples, although small amounts of these nuclides (about 2-5% of their concentrations in the initial glass) were found to be incorporated into mineral phases. These results show the importance of understanding the characteristics of the reaction layer. The durability of this layer may be different than the durability of the initial glass, and under the anticipated repository conditions, the durability of the hydrated layers rather than the unhydrated glass may control the nuclide release. Detailed analysis of the hydrated reaction layers using SEM and AEM techniques are in progress to better characterize the structure and compositions of hydrated reaction layers. A presentation on "Integrated Glass Alteration Tests" (Bates) was given to the NWTRB in August 1990.

Work has continued to catalog the secondary phases formed on steam-reacted SRL 165 and SRL 202 samples produced in experiments performed previously. The complete results of these experiments will be compiled in a topical report with results of other experiments in steam at elevated temperatures.

Analyses show the wealth of information available through AEM analysis. The similarity of the solids produced in steam (prior to secondary phase formation) and leaching tests offers the first good evidence that these environments can be simply related, and that they provide a means of accelerating the reaction. Further analyses will be performed on other examples to provide evidence of the glass reaction mechanism through solids analysis.

The summary for the manuscript by J. Bates, J. Bradley, W. Ebert, and W. Bourcier entitled "Mechanistic Interpretation of Glass Reaction: Input to Kinetic Model Development" was submitted by ANL to LLNL for review. The manuscript describes the results of AEM investigation of samples of SRL 165U glass reacted as part of the series of tests performed to determine the effect of radiation on glass reaction.

Geochemical Interactions

The flow-through dissolution tests of a simple analogue glass were completed. These tests are similar to the previous flow-through tests except that the pH buffer solution was doped with silica at a level of about 1/2 of amorphous silica saturation. The tests continued until the rate of release of glass species reached an approximately constant value indicating the achievement of steady state conditions (after 3-5 weeks). Those rates will allow the determination of the affinity term in the rate equation for glass dissolution. Analysis of the results has begun. A presentation on "Experimental Bases for Glass Modeling" (Knauss) was given to the NWTRB in August 1990.

The next set of flow-through tests is being planned.

Subactivity 1.5.2.2.3 - Cooperative Testing With Waste Producers. A technical exchange meeting was held at ANL to discuss the testing and evaluation of glass-based defense high-level waste forms. The discussions addressed technical aspects of glass-waste form production problems (process control models and testing data), and glass-waste form performance problems (release rate models and testing data). Both problem areas benefitted from this technical exchange, and future technical exchanges, along with improvements in coordinating their modeling and testing activities, are anticipated.

2.6.2.4 Activity 1.5.3.1 - Integrate Scenarios for Release from Waste Packages

Technical input was provided and reviewed for a draft of the Working Group 2 joint paper (LLNL, PNL, University of California/Berkeley) "Preliminary Calculations of Release Rates for ^{99}Tc, ^{129}I, ^{135}Cs, and ^{231}Np from Spent Fuel in a Tuff Repository" (Apted et al.).

Formal Interface discussions with the Container Material and Near Field technical areas are ongoing.

Staff reviewed a draft NRC staff report entitled "Phase 1 Demonstration of the NRC's Capability to Conduct a Performance Assessment for a High-Level Waste Repository."

LLNL organized and hosted a workshop on July 26 on the human intrusion drilling scenario development for the Project Office performance assessment activity. The meeting was attended by representatives from the Project Office, SNL, and LLNL. Technical presentations were made by staff members from all three organizations. The workshop focused on the sequence of events and their immediate effects (e.g., loss of fluids). SNL presented a draft Problem Definition Memo (PDM) which focused on two hydrologic issues. The PDM was discussed, but closure was not achieved. The workshop was successful in that a legitimate sequence of events could be identified. A second meeting to settle the hydrologic aspects was planned for September.

The MOU between LLNL and SNL regarding transfer of scenario information from SNL to LLNL was drafted. In-house review was completed and the draft was sent to SNL peers for review. SNL review comments on the MOU were incorporated and the MOU was revised. The MOU is intended to hold for the lifetime of the scenarios task. Scheduled delivery of information will be updated at least annually. Other revisions will be made as needed.

The status of the human intrusion scenario was presented August 1-3 to the PACE meeting held in Las Vegas. The two problems being assessed by the group are a quick drain where drilling continues some distance below the repository horizon to a highly permeable zone, and a fixed source where lost drilling fluid is ponded and seeps (via fractures/matrix flow) or is not ponded and flows horizontally, seeking fractures. The highly permeable zone is intended to simulate an interconnected fracture zone. While there was little discussion about the LLNL/SNL decision not to assess the classical human intrusion issue (i.e., waste brought to surface), a member of the NWTRB expressed concern over the validity of the two scenarios, and he proposed a scenario including drilling to the water table. Drilling to the water table might pose an interesting phenomena, particularly if it is repeated, but LLNL and SNL felt that it would shed little information in regards to site characterization since it effectively short-circuits the site.

The Human Intrusion Drilling Scenario workshop held at LBL on September 12 was attended by LLNL, SNL, LBL, PNL, Project Office, and SAIC, with SNL and LLNL staff making the presentations. The second workshop focused on hydrology issues. In a previous meeting (late August), SNL had made some changes to its proposed hydrologic problems or at least the modeling of those problems. Rather intense discussions followed, and it was agreed some changes were needed for the quick drain problem. SNL was assuming, in essence, a bathtub with an open drain. Even assuming drift seals hold, LLNL and others believe a fracture/matrix flow model to be more appropriate and representative. The drain could be modeled as a large fracture. From these discussions, a better understanding of the source term input was achieved. SNL agreed to take the LLNL (Buscheck) proposed modeling solution under consideration, and LLNL (MacIntyre) agreed to coordinate source term statements of work (LLNL, PNL, and LBL). Results were presented by LLNL (Buscheck) from a discrete fracture/matrix model of the impact of introducing approximately one million gallons of drilling water into an emplacement panel. Also considered was the

effect of fracture coatings where the fracture coating has the effect of reducing the matrix permeability in the immediate vicinity of the fracture.

Additional review comments on the NRC Performance Assessment rewrite of the paragraph commenting on scenarios were provided to SAIC/T&MSS.

LLNL staff is collaborating on a scenarios paper with SNL for the International Topical Meeting on High Level Radioactive Waste Management next April. An extended summary of a paper entitled "Disruptive Scenario Aspects Important to Source Term Performance" (MacIntyre et al.) was prepared for the same conference.

2.6.2.5 Activity 1.5.3.2 - Develop Geochemical Speciation and Reaction Model

Subactivity 1.5.3.2.1 - Develop Data Base for Geochemical Modeling. Hand verification of the data base was completed and all errors were corrected. Approximately 200 changes were made to the 17,000 items checked. Most were typographical errors, but systematic changes have been made to conform to the new SUPCRT algorithms and species. The data base is now under formal QA controls.

The CATCH code has been received from the NIST and is being modified to provide automated data analysis of large groups of data (such as by element). The code will be modernized to meet Project standards.

Work was completed by ORNL on the modification of EQ3 to implement their GRESS algorithms for sensitivity analysis (Horwedel et al., 1990).

The data base handling codes have been modified to provide the capability of providing single-data-source files, such as NEA or SUPCRT, for users with specific QA requirements utilizing those sources.

Subactivity 1.5.3.2.2 - Develop Geochemical Modeling Code. Changes have been made in the handling of high-ionic strength solutions to provide unified data files for the Pitzer formalisms. The data for these files have been verified.

A new menu-style input file has been tested and verified.

Minor errors were corrected, mostly dealing with outdated features which could be potentially misused. A-zero is now read from the data file; alkalinity is no longer calculated. A new CO_2 polynomial has been included, and there is a new expression for the activity of water which explicitly uses the B-dot formalism. Errors leading to code failure in high-ionic strength scenarios were corrected, as were errors leading to very slow execution of kinetics runs.

Work continues on outlining requirements for the License Application Design version of EQ3/6. Major issues are the mechanism for handling temperature extrapolation and the ways of dealing with initial data that use differing formalisms for ionic strength. Initial strategies for dealing with simple sorption were outlined (Viani, 1988).

The current status of EQ3 and EQ6 were reported (Wolery et al., 1990). The proceedings of a workshop on geochemical modeling were completed and distributed (Jackson and Bourcier, 1986).

The following laboratory work was done in support of the above activity:

High-Temperature Calorimetry

The TIP for the calorimeter was completed. Measurements to determine day-to-day reproducibility of the blank correction are underway to determine the effect of room temperature on calorimeter stability.

The quartz thermometers were cross-calibrated to the NIST-validated mercury-in-glass thermometers and calibration of the titrant pump was completed. This completes the variable temperature calorimeter calibration. The pH monitoring system was recalibrated. LLNL is in a position to initiate quality affecting measurements.

High-Temperature Spectroscopy

Measurements of solutions of varying metal-ligand ratio for the Pr-diglycolate and Pr-acetate systems were made for a range of temperatures with the Guided Wave fiber optic spectrometer. Preliminary data analysis indicated some difficulties in resolution of the spectrometer.

Photoacoustic and Photothermal Deflection Spectroscopy

The remote optical fiber photoacoustic spectroscopy (PAS) system was modified to reduce or eliminate grounding problems. A manuscript describing the remote-fiber PAS system, titled "Remote Photoacoustic Measurements in Aqueous Solutions Using an Optical Fiber" (Russo et al.), was prepared and submitted for publication in Reviews of Scientific Instruments.

For convenience of changing solutions inside a gloved inert atmosphere box, a flow cell was incorporated into the remote-fiber PAS system. Since the acoustic response of the flow cell is significantly different than that of a static cell, the system characteristics had to be redetermined with the new configuration. Unfortunately, there was not enough flexibility in the z translational stage to position the flow cell properly, and the inert box had to be opened. Since the set-up could not be moved, the flow cell was moved into the laser lab to check out the flow cell in the absence of the fiber optic.

The method of measuring the power of the laser beam after passage through the absorption cell with a photodiode was tested and found to give the correct response. After this testing, the flow-through cell was reassembled in the inert atmosphere box and again coupled to the laser via an optical fiber system. Solutions of Am-243 were measured with the system and a Beer's law plot was obtained.

Investigation of the carbonate complexation of U^{4+} was initiated. A flow-through cell system was constructed. This system contains a compartment for the potentiometric reduction of U(VI) to U(IV) before the solution passes into the absorption cell. Tests are being conducted to determine the optimum

conditions for the reduction process. A paper entitled "Remote Measurements of Actinide Species Using an Optical Fiber and Photoacoustic Spectroscopy" (Russo et al.) was accepted for presentation at the November MRS Symposium in Boston.

2.6.2.6 Activity 1.5.3.3 - Generate Models for Release from Spent Fuel

Subactivity 1.5.3.3.1 - Generate Release Models for Spent Fuel Models. The release rate from fragmented spent fuel pellets depends explicitly on the surface area of the fragments. For different statistical sets of fragment size classes, and for dissolution of fragments over long periods of time, the fragment surface area along with its time dependence must be incorporated in a model for radionuclide release rate. A modeling approach is being initiated that subdivides fragment volumes into sets of pyramidal sub-volumes. This approach, to represent surface area and volume, is an analog of modeling developments proposed to describe the oxidation weight gain for a set of spent fuel fragments. For spent fuel dissolution rate modeling, the surface area decomposes into two spatial point sets: one set of points is the area of the exposed grain volumes and the other set is the area of exposed grain boundaries. Analytical expressions for area measures of these two spatial point sets are being formulated in terms of the statistical number density of grain volumes and grain boundaries.

A presentation on "Geochemical Simulation of Spent Fuel Dissolution" (Bruton) was given to the NWTRB in August 1990. The presentation described the current status of geochemical models that have been applied to interpret spent fuel tests.

2.6.2.7 Activity 1.5.3.4 - Generate Models for Release from Glass Waste Forms

Subactivity 1.5.3.4.1 - Generate Release Models for Glass Waste Forms. An invited paper by B. Bourcier and K. Knauss entitled "A Kinetic Model for Borosilicate Glass Dissolution Based on Generic Experimental Results" was presented at the American Ceramic Society Meeting in Dallas, Texas, in April.

An invited paper by B. Bourcier and K. Knauss entitled "The Mechanisms of Borosilicate Glass Dissolution with Applications to Nuclear Waste Disposal" was presented at the V. M. Goldschmidt Conference in Baltimore, Maryland on May 2-4. The conference included an all-day session devoted to mineral and glass dissolution kinetics. Information on dissolution test and analysis methods obtained from speakers at this session will be applied to glass dissolution tests on nuclear waste glasses. In particular, it was determined that tests should be done in deuterium oxide solutions and more analyses of altered layers made using nuclear magnetic resonance spectroscopy in order to confirm some assumptions about the rate-limiting processes of glass dissolution.

The coding needed to incorporate activation energy into the rate expression in EQ3/6 was added and tested. The new coding will allow the change in the rate constant for glass dissolution as a function of temperature to be calculated internally in the code rather than having to calculate it by

hand and enter it into the input file. The EQ3/6 simulations can now be performed for polythermal reaction paths (paths with changing temperatures).

A critical evaluation was made of all current glass performance tests being carried out at ANL, LLNL, Savannah River Laboratory, PNL, and Catholic University. The tests were ranked according to their perceived merit for use in developing a glass dissolution model. The evaluation was requested as a result of the Technical Exchange Meeting in June at ANL where representatives of both the glass producers and the repository discussed the problem of relating short-term glass performance tests to repository performance. The critical evaluation was forwarded to ANL to be included as part of the meeting summary.

A presentation on "Modeling of Glass Dissolution" (Bourcier) was given to the NWTRB in August 1990.

2.6.2.8 Activity 1.5.3.5 - Waste Package Performance Assessment Model Development

Subactivity 1.5.3.5.1 - Development of System Model. The revised SIP for waste package performance assessment has been approved for interim use and has been submitted to the Project Office for management and QA review.

A paper entitled "Status of Integrated Performance Assessment of the Waste Packages and Engineered Barrier System" (O'Connell, 1990) was presented at the International Topical Meeting on High Level Radioactive Waste Management in April 1990. The paper touched on the approaches to single-waste-package and source-term modeling and summarized recent example calculations.

Work on the single-waste-package performance assessment model PANDORA-1 is in progress. Verification work on the first program and on the draft report contents was carried out and further work is continuing. Some functions were verified and plans for improvements were made. The computerized model was applied in scoping calculations (see Section 2.5.2.9).

A model for diffusion-based waste release from a waste package was developed. This model is simplified geometrically by focusing on the waste package and an assumed rubble-filled air gap. The simplified model shows clearly the sensitivities of important parameters. A newly identified parameter, important for highly soluble radionuclides, is the volume of water within the waste package; this volume helps determine the concentration driving the diffusion.

Participation of performance assessment activity personnel in the Project SBTP expert survey panels and in external contact meetings (NRC-DOE technical exchange on performance assessment, EPRI presentation at a DOE meeting, Golder Associates performance assessment workshop) provided informal exchange and access to additional scoping information and concepts.

Three abstracts were submitted by LLNL for the second International Topical Meeting on High Level Radioactive Waste Management to be held in Las Vegas, Nevada, in April 1991. These abstracts address preliminary

calculations of release rates, diffusive barrier simplified analysis applications, and sensitivity and uncertainty analysis of EBS performance.

Subactivity 1.5.3.5.2 - Development of Uncertainty Methodology. Development of uncertainty methodology is underway. The "uncertainty methodology" will be used both for uncertainty propagation (from input to output of the performance assessment models) and for numerical integration over all the waste packages to form the source term and the EBS performance to be compared to NRC performance regulations.

A computer program, Controlled Sampling Test System (CSTS), was completed. CSTS compares the performance of various sampling methods in estimating a cumulative distribution function of a model output, and implements a new sampling method, controlled sampling. The program development followed an approved Individual Software Plan. The development products to be archived include a software specification, a structured analysis using data flow diagrams and a data dictionary, a test plan, a users manual, and a theoretical report. Selected reports will be published after verification of the program and comparative testing of sampling methods has been completed. Partial verification has been done during this reporting period.

Subactivity 1.5.3.5.3 - Water Flow Into and Out of a Breached Container. No activity during this period.

2.6.2.9 Activity 1.5.4.1 - Deterministic Calculation of Releases from the Waste Package

This activity is currently in the prototype and planning stage. The revised SIP for waste package performance assessment has been approved for interim use and has been submitted to the Project Office for management and QA review.

Scoping analyses of radionuclide release rates from the EBS have been performed as part of a Project Office performance assessment calculational exercise. The approach and sample calculations were described in "Status of Integrated Performance Assessment of the Waste Packages and Engineered Barrier System" (O'Connell, 1990). Results were presented to Project Office working groups and used by them in a prototype assessment of total system performance. Release rate calculations from several participants were combined in a joint report in review at the Project Office.

The scoping calculations illustrate the importance of parameters in the areas of heat transfer, local ground-water hydrology, geochemistry-waste form interactions, and EBS design. Three different potential water-waste contact modes were examined for several radionuclides of high and low solubility. The results of these scoping calculations can assist in guiding further conceptual development and performance allocations.

2.6.2.10 Activity 1.5.4.2 - Probabilistic Calculation of Releases from the Waste Package

This activity is currently in the prototype and planning stage. The revised SIP for waste package performance assessment has been approved for interim use and has been submitted to the Project Office for management and QA review.

2.6.2.11 Activity 1.5.5.1 - Determine Radionuclide Transport Parameters

Subactivity 1.5.5.1.1 - Radionuclide Distribution in Tuff Wafers. Activity in this area has been reduced due to a lack of funding. Additional tuff wafer and filter samples were obtained from of ANL. These samples are being analyzed to help determine the amount of actinides likely to be released and transported in a colloidal form from the waste package.

Samples from two tuff cups that had been included in actinide-glass waste-form tests were polished, mounted, photographed, and set up for step-scan analysis of the tracer isotopes with the ion microscope. These samples will allow transport of released actinides in tuff to be measured over 1-2 cm, a significantly greater distance than in previously analyzed 2 mm thick samples.

Subactivity 1.5.5.1.2 - Radionuclide Distribution in Tuff Cores. Work continued in the areas of the SIP, program planning and QA. Technical procedures were written for data acquisition with the Cameca ion microscope in the depth profiling mode and for data analysis. Staff participated in the software QA working group and reviewed the Project SQAP. Revisions were made in the draft individual SQAP (ISP) prepared for the Cameca IMS/3F MONITOR program, and examples were obtained of ISPs and test plans for other software.

Maintenance and development of the Cameca ion microscope emphasized software development and calibration standards. The MONITOR program was modified to add the option of allowing the user to monitor the primary beam during a depth profile. This option, the most difficult code change to date, will allow the user to correct for primary beam drifts when doing post-run analysis of data gathered in the depth profiling mode. The option was tested and implemented for routine analysis. As part of its scheduled maintenance, the Cameca detection system was thoroughly inspected and tested for malfunctions. Based on pulse-height spectra, noise, deadtime, and other indicators, the detection system was found to be in good shape.

Standards are necessary to obtain accurate measurements of elemental concentrations in materials of interest to the Project. Samples of a UO_2 fuel pellet, Incoloy 825, glass, a copper nickel alloy, and Topopah Spring Tuff were prepared for ion implantation in order to produce a set of calibration standards for trace elements in these materials. The values for uranium isotopes in NBS SRM #612 glass that had been analyzed over the last four years were also compiled and evaluated. A program was written to calculate elemental concentrations from calibration values and ion counts for multiple data sets.

Progress continued in establishing standards for analysis of samples with receipt and mounting of polished fuel pellets, alloys, glasses, and tuff wafers for ion implants. The capability to analyze lanthanide elements at low concentrations in glasses and glassy rocks (e.g., Project samples) can be attained with the development of a peak-stripping program to correct for interferences in the lanthanide region and with the availability of appropriate calibration standards for the ion microscope. Low La, Ce, Nd, and Pr abundances were measured with the ion microscope in three SRM glass samples. The response appears linear; however, values are not well enough known in the 0.02 ppm and 1.0 ppm standards to allow their use with Project samples. Additional data for lanthanide elements in these standards were requested. Congruence of results with three techniques is the NIST protocol for certifying standards; samples of the SRM glass were submitted for Inductively Coupled Plasma-Mass Spectroscopy (ICP-MS) and INAA analysis of lanthanide elements and other trace elements as an intercalibration with the Scanning Ion Mass Spectroscopy (SIMS) technique.

Design and acquisition of equipment to do actinide transport experiments commenced. The design of a second-generation core-flow-through system incorporates the following features:

1. Confining and pore pressure typical of the repository
2. Low-volume inert-material fluid lines and reservoirs
3. Variable flow rate
4. Sensors for impedance tomography
5. Pressure differential monitoring
6. Adjustable core size
7. Computer-control

Both chemical and hydrological transport will be studied simultaneously with this system.

Preparation of the diffusion cells for scoping experiments continued. Stirrer design for the diffusion cells was modified, and disc-shaped stirrers constructed. A non-toxic dye was identified and obtained; however, leak tests were postponed due to problems with the spectrometer needed for detection. A temperature probe and recorder were also obtained from Instrument Loan to better monitor the diffusion cell temperature.

Samples from a tuff cup that had been included in an actinide-glass waste-form tests were analyzed on the SIMS for U, Pu, Li, Zr, Si, and Al concentrations. An invited abstract discussing the results of these and other tests, entitled "Actinide Transport in Topopah Spring Tuff: Pore Size, Particle Size, and Diffusion" (ten Brink) was submitted to the MRS fall meeting.

A recording system to monitor the temperature of room air, the waterbath, and the diffusion cells was set up. Leak tests were again postponed due to the spectrometer needed for detection being out for repair.

Interpretation and analysis of existing data and samples continued. Application of fracture-matrix hydrological transport models to data from actinide diffusion experiments was initiated after discussions with the near-field hydrology task. In addition, techniques to determine the three-

dimensional pore structure of the tuff samples were identified, and evaluation began of their usefulness. Information on the fracture and pore structure is necessary to adequately model and predict actinide transport in non-homogeneous material such as the repository and near-field.

2.6.3 Characteristics and Configurations of the Waste Packages (SCP Section 8.3.4.3)

No significant activities were carried out during the reporting period.

2.6.4 Waste Package Production Technologies (SCP Section 8.3.4.4)

Accelerated thermal/mechanical processing feasibility studies and accelerated inertial welding studies were completed by Babcock & Wilcox (B&W), and samples were sent to LLNL for further evaluation. These samples included inertial welded, 18-inch diameter rings fabricated from roll-and-welded alloy 825 and CDA 715, and inertial welded, 4-inch diameter hollowed bars fabricated from CDA 613.

Post-test characterization studies were conducted at LLNL on these inertial welded pieces. This characterization consisted of macroetching, cross-sectional metallographic evaluations, and microhardness measurements. These studies indicate that inertial welding appears to be a viable method for closing disposal containers, but that additional testing and trial runs are required to establish optimum process parameters.

Due to funding restrictions, the Phase 2 work scope (waste package closure and inspection studies at Babcock & Wilcox, Inc. was terminated. All test specimens, extra stock material, documents and QA records, and a final report draft were transmitted to LLNL to close out the subcontract. The earlier work conducted as feasibility studies (Phase I) was recently published (Stein et al., 1990).

2.6.5 Waste Package Performance (SCP Section 8.3.5.9)

2.6.5.1 Activity 1.4.1.1 - Integrate Design and Materials Information (Metal Container)

Internal activity plans and technical implementing procedures were prepared and approved to perform characterization of the container materials. The tasks associated with this activity also passed a readiness review to permit work initiation under an approved program. However, due to funding restrictions, this activity has been put on hold.

2.6.5.2 Activity 1.4.1.2 - Integrate Design and Materials Information (Alternate Barriers Investigation)

LLNL was directed by the Project Office to stop work on this activity and to provide a "turn over package" to the Project Office. This directive was

completed in June 1989; there was no progress made during the reporting period.

2.6.5.3 Activity 1.4.2.1 - Selection of the Container Materials for the License Application Design

Subactivity 1.4.2.1.1 - Establishment of Selection Criteria and their Weighting Factors. The preliminary Selection Criteria report for metallic, high-level radioactive waste containers was submitted to the Project Office for Project review and approval on August 31, 1990.

2.6.5.4 Activity 1.4.2.2 - Degradation Modes Affecting Candidate Copper-Based Container Materials

Subactivity 1.4.2.2.1 - Assessment of Degradation Modes in Copper-Based Materials. This activity was completed (refer to TSR-2, Section 2.5.5.4).

Subactivities 1.4.2.2.2 through 1.4.2.2.8 - Laboratory Test Plan for Copper-Based Materials and Activity 1.4.2.3 - Degradation Modes Affecting Candidate Austenitic Materials. The Slow Strain Rate Tensile tests being conducted at ANL for propensity to stress corrosion cracking were completed for the six candidate container materials in simulated J-13 well water. More sensitive, long-term crack growth tests were also completed on the three austenitic alloys (alloy 825, 304L and 316L stainless steels) in simulated J-13 well water at 93°C.

In addition to the above, the effects of radiolysis on alloy corrosion and on water chemistry changes are also underway at ANL. Testing was initiated at LLNL to measure the conditions which affect the pitting potentials for the six candidate materials.

Three reports were published concerning corrosion behavior of copper or copper-based alloys: Kundig et al., (1990), Yunker (1990), and Smith (1990).

2.6.5.5 Activity 1.4.2.3 - Degradation Modes Affecting Candidate Austenitic Materials

Progress is discussed under Section 2.6.5.4.

2.6.5.6 Activity 1.4.2.4 - Degradation Modes Affecting the Ceramic-Metal, Bimetallic/Single Metal, or Coatings and Filler System

This activity was on hold during the reporting period, as was discussed in Section 2.6.5.2.

2.6.5.7 Activities 1.4.3.1 and 1.4.3.2 - Models for Copper and Copper-Alloy Degradation and Models for Austenitic Material Degradation

Efforts this period were devoted to identifying experiment-based models for localized corrosion and stress corrosion cracking of both austenitic and copper-based alloys. Inquiries were made to well-established model programmers around the country to solicit their advice and assistance. These models will be used once the laboratory data that were mentioned earlier, and other pertinent data, are made available.

2.6.5.8 Activity 1.4.3.3 - Models for Degradation of Ceramic-Metal, Bimetallic/Single Metal, and Coatings and Filler Alternative Systems

This activity was on hold during the reporting period, as was discussed in Section 2.6.5.2.

2.6.5.9 Activity 1.4.4.1 - Estimates of the Rates and Mechanisms of Container Degradation in the Repository Environment for Anticipated and Unanticipated Processes and Events, and Calculation Failure Rate as a Function of Time

Subactivity 1.4.4.1.1 - Deterministic Calculation of Rates of Container - Degradation in the Repository Environment. This activity is currently in the prototype and planning stage. The revised SIP for waste package performance assessment has been approved for interim use and has been submitted to the Project Office for management and QA review. Initial planning and discussions of interfaces with other technical areas is under way.

Subactivity 1.4.4.1.2 - Probabilistic Calculation of Rates of Container Degradation and Distribution of Time to Initiation of Release of Radionuclides from the Waste Packages. This activity is currently in the prototype and planning stage. The revised SIP for waste package performance assessment has been approved for interim use and has been submitted to the Project Office for management and QA review.

Scoping calculations (see Section 2.6.2.9) indicate the importance of the distribution of times to initiation of release of radionuclides from the numerous waste packages in the total repository.

2.6.5.10 Activity 1.4.5.1 - Determination of Whether the Substantially Complete Containment Requirement is Satisfied

This activity is currently in the prototype and planning stage. The revised SIP for waste package performance assessment has been approved for interim use and has been submitted to the Project Office for management and QA review.

2.6.5.11 Activity 1.5.5.2 - Radionuclide Transport Modeling in the Near-Field Waste Package Environment

Subactivity 1.5.5.2.1 - Validation of Near-Field Transport Model Using Laboratory and Field Experimental Data. No significant activities were carried out during the reporting period.

Subactivity 1.5.5.2.2 - Application of Near-Field Transport Model to Waste Package Releases. This activity is in prototype analysis.

2.7 PERFORMANCE ASSESSMENT

The "Retrieval Strategy Report for a High-Level Nuclear Waste Repository" by R. Flores (SAND87-2777), Milestone R848, was submitted to the Project Office for review and approval.

2.7.1 Waste Retrievability (SCP Section 8.3.5.2)

No significant progress was made during the reporting period.

2.7.2 Public Radiological Exposure - Normal Conditions (SCP Section 8.3.5.3)

2.7.2.1 Performance Assessment Activity 2.1.1.1 - Refinement of Site Data Parameters Required for Issue 2.1

No progress was made during the reporting period.

2.7.2.2 Performance Assessment Activity 2.1.1.2 - Development of Performance Assessment Activities Through the Preclosure Risk Assessment Methodology Program

Bechtel National, Inc. (BNI) has completed a preliminary criticality analysis of eleven spent fuel containers. This analysis was issued as a report for approval to SNL. The findings of the report were discussed. SNL requested that BNI perform additional criticality analyses of five container configurations to demonstrate the effect of using container dividers composed of stainless steel containing 2.0 weight % of Boron 10. The original report analyzed one hybrid container with 4 PWR assemblies with B-10 partitions. The work plan for preclosure radiological safety analyses was updated.

2.7.2.3 Performance Assessment Activity 2.1.1.3 - Advanced Conceptual Design Assessment of the Public Radiological Safety During the Normal Operations of the Yucca Mountain Repository

No progress was made during the reporting period.

2.7.3 Worker Radiological Safety - Normal Conditions (SCP Section 8.3.5.4)

2.7.3.1 Activity 2.2.1.1 - Refinement of Site Data Parameters Required for Issue 2.2

No progress was made during the reporting period.

2.7.3.2 Activity 2.2.1.2 - Advanced Conceptual Design Assessment of the Worker Radiological Safety During the Normal Operations of the Yucca Mountain Repository

No progress was made during the reporting period.

2.7.3.3 Activity 2.2.2.1 - Refinement of Site Data Parameters Required for Issue 2.2

No progress was made during the reporting period.

2.7.3.4 Activity 2.2.2.2 - Development of Performance Assessment Activities Through the Preclosure Risk Assessment Methodology Program

No progress was made during the reporting period.

2.7.3.5 Activity 2.2.2.3 - Advanced Conceptual Design Assessment of the Worker Radiological Safety During the Normal Operations of the Yucca Mountain Repository

No progress was made during the reporting period.

2.7.4 Accidental Radiological Releases (SCP Section 8.3.5.5)

2.7.4.1 Performance Assessment Activities 2.3.1.1 and 2.3.2.1 - Refinement of Site Data Parameters Required for Issue 2.3

No progress was made during the reporting period.

2.7.4.2 Performance Assessment Activity 2.3.1.2 - Determination of Credible Accident Sequences and Their Respective Frequencies Applicable to the Yucca Mountain Repository

SAND88-7061, entitled "Preclosure Radiological Safety Analysis for Accident Conditions of the Yucca Mountain Repository: Underground Facilities" (Ma et al.), was submitted for Project review. SAND90-7051, entitled "Analysis of Scenarios and Potential Radiological Consequences Associated With U.S. Military Aircraft Crashes for the Yucca Mountain Repository" (Ma et al.), is currently in SNL technical review. It is anticipated that the report will be submitted to the Project Office for review in November 1990.

2.7.4.3 Performance Assessment Activity 2.3.1.3 - Development of Candidate Design-Basis Accidents for the Yucca Mountain Repository

No progress was made during the reporting period.

2.7.4.4 Performance Assessment Activity 2.3.2.2 - Consequence Analyses of Credible Accidents at the Yucca Mountain Repository

No progress was made during the reporting period.

2.7.4.5 Performance Assessment Activity 2.3.2.3 - Sensitivity and Importance Analyses of Credible Accidents at the Yucca Mountain Repository

No progress was made during the reporting period.

2.7.4.6 Performance Assessment Activity 2.3.2.4 -Documentation of Results of Safety Analyses and Comparison to Applicable "Limiting" Values

No progress was made during the reporting period.

2.7.5 Ground-Water Travel Time (SCP Section 8.3.5.12)

2.7.5.1 Activity 1.6.2.1 - Model Development

Subactivity 1.6.2.1.1 - Development of a Theoretical Framework for Calculational Models. "Laboratory Research Program to Aid in Developing and Testing the Validity of Conceptual Models for Flow and Transport Through Unsaturated Porous Media" (Glass, 1990) was presented at the Geoval-90 Symposium in Stockholm, Sweden, May 13-19, 1990. The presentation of the paper constituted fulfillment of Milestone P651.

"Computed Effects of Rock Heterogeneities on Water Infiltration Into Small-Pore Unsaturated Rock" (Eaton) was technically reviewed and was sent to the Project Office for policy review. The paper will be presented at the CUBE Symposium, November 27-30, 1990, in Sante Fe, New Mexico.

"Laboratory Scale Program for Testing Fracture Flow and Transport Models" (Glass and Tidwell), and "An Experimental Program for Testing the Validity of Flow and Transport Models in Unsaturated Tuff: The Yucca Mountain Project" (Shephard et al.) have been completed and approved for distribution. Both reports have been submitted for presentation at the 1991 International Topical Meeting on High Level Radioactive Waste Management.

Subactivity 1.6.2.1.2 - Development of Calculational Models. No progress was made during the reporting period.

2.7.5.2 Activity 1.6.2.2 - Verification and Validation

Subactivity 1.6.2.2.1 - Verification of Codes. The PACE-90 "nominal configuration" analysis milestone was met by the oral presentations on April 24-26, 1990, and by the publication of an internal draft report, SLTR90-3001, "Summary Report on the PACE-90 Radionuclide Transport Problem for a 'Nominal' Hydrogeologic Configuration." The remainder of the PACE-90 milestones were met by presentations in July 1990 of preliminary "perturbed configuration" results for basaltic volcanism, human intrusion, and climate change. At the September 30, 1990, year-end meeting, comparisons of PACE-90 work against prior similar work were made, sensitivity studies presented, and draft Problem Definition Memos for more complex volcanism and human intrusion problems discussed.

The PACE-90 "nominal configuration" exercise was completed by SNL staff. A one-dimensional ground-water flow simulation for the 0.001 mm/yr was calculated using the FFLOPM computer code. Based on the results from the FFLOPM calculation, radionuclide transport simulations were performed using the NEFTRAN computer code. The results of these analyses were presented at the April Working Group 1 meeting.

The paper "COVE2A Benchmarking Calculations using LLUVIA" (Hopkins, 1990) was published as a SAND report in August.

Subactivity 1.6.2.2.2 - Validation of Models. Technical staff participated in a site visit by the NRC and the CNWRA on May 22, 1990. The site visit included discussions and tours of unsaturated flow laboratory facilities.

SNL staff attended and presented information concerning the flow of water in unsaturated zones at the Hydrology Peer Review Panel meeting in Las Vegas, Nevada, on June 4-6, 1990.

On September 11-12, 1990, SNL staff participated in the "Radionuclide Adsorption Workshop" conducted by LANL. Topics included ongoing investigations, problems associated with applying current transport models to performance assessment tasks, and the identification of key adsorption processes that must be incorporated into transport models.

On September 13 and 14, 1990, SNL staff attended a technical symposium entitled "Fractures, Hydrology, and Yucca Mountain," organized by the USGS CASY. Of particular interest were presentations concerning the characterization of fracture void structure that could be used to infer hydraulic properties, and presentations outlining efforts to characterize single fractures and fracture networks using various statistical and fractal techniques.

2.7.5.3 Activity 1.6.3.1 - Analysis of Unsaturated Flow System

Subactivity 1.6.3.1.1 - Unsaturated Zone Flow Analysis. No progress was made during the reporting period.

Subactivity 1.6.3.1.2 - Saturated Zone Flow Analysis. No progress was made during the reporting period.

2.7.5.4 Activity 1.6.4.1 - Calculation of Pre-Waste-Emplacement Ground-Water Travel Time

Subactivity 1.6.4.1.1 - Performance Allocation for Issue 1.6. Reported under Subactivity 1.6.4.1.2.

Subactivity 1.6.4.1.2 - Sensitivity and Uncertainty Analyses of Ground-Water Travel Time. Contract workers at Purdue University continued work to validate the latest Point Estimate Methods (PEMs). SNL staff are writing the software to implement these PEMs. An RS/Explore procedure will be used as an alternative to the Latin Hypercube Sampler (LHS) for generating input decks for performance assessment ground-water travel time simulation. Ultimately, SNL will run independent validation exercises of the methodology, and then incorporate the method as part of the overall performance assessment methodology.

SNL staff attended PACE meetings on the nominal case and disturbed scenarios. Work commenced to revise the nominal case hydrostratigraphy created for the earlier PACE exercises. Staff are reviewing hydrologic, mechanical, and bulk property data from the Yucca Mountain site to determine whether hydrologic data can be estimated from other tuff properties. Several hydrologic parameters were analyzed as functions of porosity.

SNL staff presented "Unsaturated Zone Ground-Water Travel Times Performance Assessment" to the Unsaturated Zone Hydrology Peer Review Panel in Las Vegas, Nevada, on June 6, 1990. The presentation emphasized the probabilistic basis for current calculations.

The paper "LLUVIA: A Program for One-Dimensional, Steady-State Flow Through Partially Saturated Porous Media" (Hopkins and Eaton) was published as a SAND report in May.

SNL staff investigated the effects of meter-sized heterogeneities on predominantly one-dimensional flow to determine whether effective material properties exist for the one-dimensional case. Multiple realizations have been calculated for randomly-distributed spatial distributions of rock with assigned permeabilities that vary up to six orders of magnitude. An abstract of these results has been written for presentation at the November CUBE Symposium.

A presentation on performance assessment was made by SNL staff to the NCAR on August 7, 1990, in Boulder, Colorado.

Subactivity 1.6.4.1.3 - Determination of the Pre-Waste Emplacement Ground-Water Travel Time. Reported under Subactivity 1.6.4.1.2.

2.7.5.5 Activity 1.6.5.1 - Ground-Water Travel Time After Repository Construction and Waste Emplacement

No progress was made during the reporting period.

2.7.5.6 Activity 1.6.5.2 - Definition of the Disturbed Zone

No progress was made during the reporting period.

2.7.6 Total System Performance (SCP Section 8.3.5.13)

2.7.6.1 Performance Assessment Activity 1.1.2.1 - Preliminary Identification of Potentially Significant Release Scenario Classes

Subactivity 1.1.2.1.1 - Preliminary Identification of Potentially Significant Sequences of Events and Processes at the Yucca Mountain Repository Site. Event trees to examine the possible radionuclide release paths following eight basic processes or events (nominal flow, human intrusion, basaltic volcanism, tectonics, climate change, closure of repository, gas-phase releases, and nonintrusive human activities) will be constructed. Each preliminary tree will be issued as a letter to Project participants working in the field of the tree, with requests to comment on its completeness and requests to reference technical arguments for eliminating from further consideration those combinations of events and processes which will not lead to significant radionuclide release.

Preliminary event trees for nominal flow, human intrusion, and basaltic volcanism have been completed and the associated report, "Progress Report on the Construction of Event Trees in Support of Scenario Development" (Barr et al.), is in SNL line review. To date, several experts have offered valuable input. Work has begun on the tectonics event tree.

It is planned that preliminary estimates of total system behavior will be made periodically. Such estimates are based on the current state of knowledge of potential radionuclide releases, transport phenomena, expected flow, and disruptive scenarios. A prediction process is currently underway, and a simple radionuclide source term is being constructed. A total system analyzer is being assembled using LHS, a Latin Hypercube Sampler for Monte Carlo simulation, and for the unsaturated zone, the one-dimensional code TOSPAC. Planned enhancements to the analyzer include use of the two-dimensional codes NORIA and FEMTRAN for UZ modeling and ISO-QUAD for saturated zone modeling. Both of these tools will be used to make a system behavior estimate.

Abstracts entitled "Scenarios and Performance Assessment Exercises: Details of the Big Picture" (Barr et al.), "Effect of Low-Permeability Layer on Calculated Gas Flow at Yucca Mountain" (Ning et al.), "Total-System Analyzer for Performance Assessment of Yucca Mountain" (Cummings et al.), and "A Parametric Model for Performance Assessment" (Wilson) have been accepted for presentation at the 1991 International Topical Meeting on High Level Radioactive Waste Management.

Subactivity 1.1.2.1.2 - Preliminary Identification of Potentially Significant Release Scenario Classes. Activity reported under Subactivity 1.1.2.1.1.

2.7.6.2 Performance Assessment Activity 1.1.2.2 - Final Selection of Significant Release Scenario Classes to be Used in Licensing Assessments

No progress was made during the reporting period.

2.7.6.3 Performance Assessment Activity 1.1.3.1: Development of Mathematical Models of the Scenario Classes

Subactivity 1.1.3.1.1 - Development of Models for Release Along the Water Pathways. Activity reported under Subactivity 1.1.2.1.1.

Subactivity 1.1.3.1.2 - Development of a Model for Gas-Phase Releases. Studies of the sensitivity of travel time to various parameters are being conducted using TGIF and PATHLINE. A presentation will be made at the International Topical Meeting on High Level Radioactive Waste Management in April 1991.

Subactivity 1.1.3.1.3 - Development of a Model of Releases Through Basaltic Volcanism. Activity reported under Subactivity 1.1.2.1.1.

Subactivity 1.1.3.1.4 - Development of a Model of Releases Through Human Intrusion. Activity reported under Subactivity 1.1.2.1.1.

2.7.6.4 Performance Assessment Activity 1.1.4.1 - The Screening of Potentially Significant Scenario Classes Against the Criterion of Relative Consequences

No progress was made during the reporting period.

2.7.6.5 Performance Assessment Activity 1.1.4.2 - The Provision of Simplified, Computationally Efficient Models of the Final Scenario Classes Representing the Significant Processes and Events Mentioned in Proposed 10 CFR 60.112 and 60.115

No progress was made during the reporting period.

2.7.6.6 Performance Assessment Activity 1.1.5.1 - Calculation of an Empirical Complementary Cumulative Distribution Function

No progress was made during the reporting period.

Subactivity 1.1.1.5.1.1 - Construction of the Total-System Simulator. No progress was made during the reporting period.

Subactivity 1.1.5.1.2 - Construction of the Joint Probability Distribution to Be Used in the Licensing-Assessment Calculations. No progress was made during the reporting period.

Subactivity 1.1.5.1.3 - Construction of an Empirical Complementary Cumulative Distribution Function for the Licensing Action. No progress was made during the reporting period.

2.7.7 Individual Protection (SCP Section 8.3.5.14)

2.7.7.1 Activity 1.2.1.1 - Calculation of Doses Through the Ground-Water Pathway

No progress was made during the reporting period.

2.7.7.2 Activity 1.2.2.1 - Calculation of Transport of Gaseous Carbon-14 Dioxide Through the Overburden

No progress was made during the reporting period.

2.7.7.3 Activity 1.2.2.2 - Calculation of Land-Surface Dose and Dose to the Public in the Accessible Environment Through the Gaseous Pathway of Carbon-14

No progress was made during the reporting period.

2.7.8 Ground-Water Protection (SCP Section 8.3.5.15)

2.7.8.1 Analysis 1.3.1.1 - Determine Whether Any Aquifers Near the Site Meet the Class I or Special Source Criteria

The paper "Computed Distributions of Residual Shaft Drilling and Construction Water in the Exploratory Facilities at Yucca Mountain, Nevada" (Eaton and Peterson, 1990) was presented at the International Topical Meeting on High Level Radioactive Waste Management, Las Vegas, Nevada, and published in the conference proceedings.

Activity 1.3.1.1.1 - Synthesis and Evaluation of Hydrologic and Environmental Information Needed to Determine Whether Aquifers at the Site Meet the Special Source Criteria. No progress was made during the reporting period.

Activity 1.3.1.1.2 - Synthesis and Evaluation of Demographic and Economic Data Needed to Determine Whether Class I or Special Sources of Ground Water Exist. No progress was made during the reporting period.

2.7.8.2 Analysis 1.3.2.1 - Determine the Concentrations of Waste Products in Any Special Source of Ground Water During the First 1,000 Years After Disposal

No progress was made during the reporting period.

Activity 1.3.2.1.1 - Synthesis and Evaluation of Releases of Waste Products to Special Sources of Ground Water During the First 1,000 Years After Disposal. No progress was made during the reporting period.

2.7.9 Performance Confirmation (SCP Section 8.3.5.16)

No progress was made during the reporting period due to budgetary constraints.

2.7.10 NRC Siting Criteria (SCP Section 8.3.5.17)

No progress was made during the reporting period due to budgetary constraints.

2.7.11 Higher-Level Findings--Postclosure System and Technical Guidelines (SCP Section 8.3.5.18)

No progress was made during the reporting period due to budgetary constraints.

APPENDIX

3.0 SCHEDULES

In late November 1989, a new proposed program schedule was announced in the Secretary's report to Congress. The new schedule was based on consideration of the duration required to obtain Yucca Mountain site access; comments from the NWTRB, the NRC, the State of Nevada, and others; and the work scope described in the SCP and the more-detailed study plans. In January 1990, the schedule presented in the Secretary's report to Congress was finalized by OCRWM in the Program Cost and Schedule Baseline (DOE, 1990e). Factors internal and external to the program, which include delays in the processing of environmental permits, study plan review, and funding levels, may continue to affect the program schedule.

This section presents the schedule for the scientific investigation program as of March 31, 1990. During the reporting period, the DOE finalized the schedule that was announced in the Secretary's report to Congress (DOE, 1989a). That schedule was provided in the previous progress report. No changes were made to the schedule in this reporting period.

Table 3.1 presents the summary milestones for the scientific investigation program. Figure 3.1 shows the relationship of the summary milestones to the major activities.

The schedule focuses on the early evaluation of site suitability of the Yucca Mountain site. With the delay in the start of exploratory shaft construction, DOE plans to take advantage of early surface-based tests if site access is obtained.

Lower-level schedules for the exploratory shaft, surface-based testing, site programs, waste package design, seals design, repository design, and performance assessment are under development. Relevant aspects of lower-level schedules may be suitable for discussion in future progress reports.

Table 3.1. Summary Milestones for Scientific Investigation[1].

Waste Package

Start Waste Package Advanced Conceptual Design	10/92
Start Waste Package License	6/96
Provide Engineered Barrier System Data To Design	7/98

Site

Start New Surface-Based Testing	1/91
Complete Deep Unsaturated Zone Drilling	3/94

Repository

Start Repository Advanced Conceptual Design	10/92
Start Repository License Application Design	6/96

Regulatory

Obtain Site Access	12/90
Issue EIS Notice of Intent	10/97
Issue EIS Implementation Plan	2/98
Issue Draft EIS	10/99
Issue Final EIS	3/01
Issue Record of Decision	4/01
Issue Site Recommendation Report to the President	4/01
Submit License Application to the NRC	10/01

ESF

Initiate Final ESF Title II Design	3/91
Start ESF Site Preparation	6/92
Start ESF Collar Construction	11/92
Complete ESF Connection	9/95
Complete ESF Geologic Drifting	11/97

[1] Table shows approved date as of March 31, 1990.

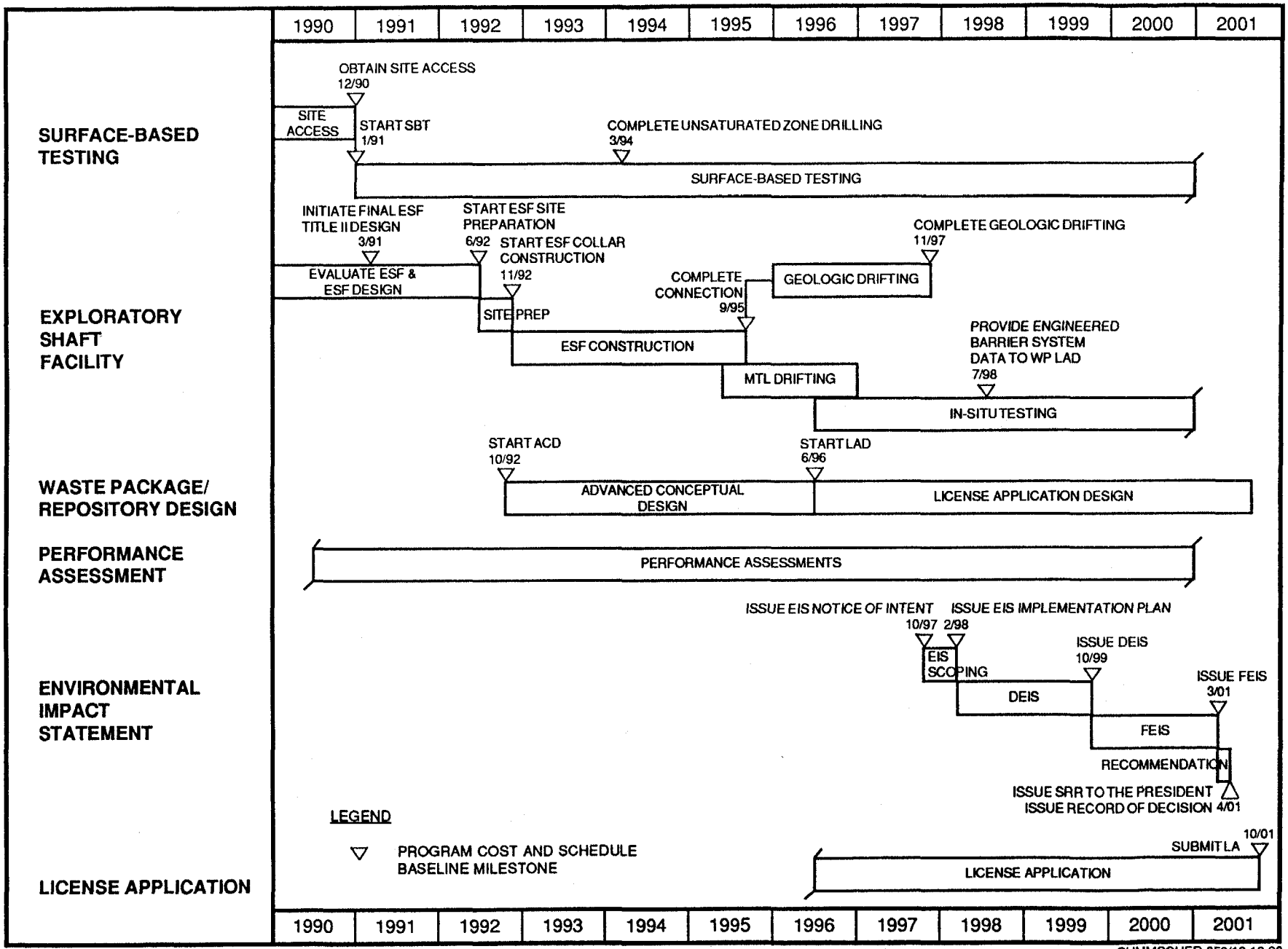

Figure 3.1. Site Characterization Summary Schedule.

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ACRONYM LIST

AC	alternating current
ACNW	Advisory Committee on Nuclear Waste
ADAPS	automated data-processing system
A/E	Architect Engineers
AEM	analytical electron microscope
AGU	American Geophysical Union
AIH	American Institute of Hydrology
ALTS	Apache Leap Test Site
ANL	Argonne National Laboratory
ANS	American Nuclear Society
APD	areal power density
APS	autocorrelation photon spectrometer
ATLAS	Alternative Licensing Application Strategy
ATM	Approved Testing Materials
AWS	Atlas Wireline Service
BLM	U.S. Bureau of Land Management
BNI	Bechtel National, Inc.
BNL	Brookhaven National Laboratory
BWR	boiling water reactor
BWRM	Board on Radioactive Waste Management
CASY	Committee for the Advancement of Science in Yucca Mountain Project
CDB	Characteristics Data Base
CIRF	Configuration Identification Request Form
CHn	Calico Hills nonwelded
CHRBA	Calico Hills Risk/Benefit Analysis
CNWRA	Center for Nuclear Waste Regulatory Analysis
COE	Corps of Engineer
CSTS	Controlled Sampling Test System
DAS	Data Acquisition System
DISA	downhole instrument station apparatus
DIW	de-ionized water
DOE	U.S. Department of Energy
DOE/HQ	U.S. Department of Energy/Headquarters
DOI	U.S. Department of Interior
DRI	Desert Research Institute
DWPF	Defense Waste Processing Facility
EBS	engineered barrier system
EBSFT	engineered barrier system field test
EEI	Edison Electric Institute
EMGC	electromagnetic ground conductivity
EMMP	Environmental Monitoring and Mitigation Plan
EPA	U.S. Environmental Protection Agency
ERWM	Environmental Restoration Waste Management
ESF	Exploratory Shaft Facility
ET	evapotranspiration
EXAS	x-ray absorption spectroscopy
FY	fiscal year
GCM	Global Climate Model
GIS	Geographic Information System
GPR	ground penetrating radar

GSA	Geological Society of America
GSIS	Geoscientific Information System
HRF	Hydrologic Research Facility
IDAS	Integrated Data Acquisition System
IAEA	International Atomic Energy Agency
I/O	input/output
INAA	Instrumental Neutron Activation Analysis
ISP	Individual SQAP
LANL	Los Alamos National Laboratory
LBL	Lawrence Berkeley Laboratory
LHS	Latin Hypercube Sampler
LLNL	Lawrence Livermore National Laboratory
MACTEC	Mac Technical Services Company
MADS	Meteorological Alert Distribution System
MCC	Materials Characterization Center
MISIS	Micro Integrated Storm Information System
MOU	Memorandum of Understanding
MRS	Materials Research Society
MSIS	Management Systems Improvement Strategy
MSS	Multi-Spectral Scanner
MT	magnetotelluric
MTL	Main Test Level
NAS	National Academy of Sciences
NCAR	National Center for Atmospheric Research
NIST	National Institute of Standards and Technology
NPS	National Park Service
NRC	U.S. Nuclear Regulatory Commission
NTS	Nevada Test Site
NWPA	Nuclear Waste Policy Act
NWTRB	Nuclear Waste Technical Review Board
OCRWM	Office of Civilian Radioactive Waste Management
ORNL	Oak Ridge National Laboratory
PAC	potentially adverse condition
PACE	Performance Assessment Calculational Exercises
PAS	photoacoustic spectroscopy
PDM	Problem Definition Memo
PEM	Point Estimate Method
PIXE	proton induced x-ray emissions
PLO	Public Land Order
PNL	Pacific Northwest Laboratory
Project Office	Yucca Mountain Project Office
psi	per square inch
PWR	pressurized water reactor
QA	quality assurance
QAPD	Quality Assurance Program Description
QARD	Quality Assurance Requirements Document
RDR	Repository Design Requirements
REECo	Reynolds Electrical and Engineering Company
SAIC	Science Applications International Corporation
SAR	synthetic aperture radar

SBTP	Surface-Based Testing Prioritization
SCA	Site Characterization Analysis
SCP	Site Characterization Plan
SCP/CD	Site Characterization Plan/Consultation Draft
SDRD	Subsystem Design Requirements Document
SEM	scanning electron microscope
SGBSN	Southern Great Basin Seismic Network
SIMS	Scanning Ion Mass Spectroscopy
SIP	Scientific Investigation Plan
SKB	Swedish Nuclear Fuel Supply Company
SMF	Sample Management Facility
SNL	Sandia National Laboratories
SOBART	Southern Basin and Range Transect
SP	Socioeconomic Plan
SPANS	Spatial Analysis System
SQAP	Software Quality Assurance Plan
SRL	Savannah River Laboratory
SA/V	surface area to volume
TCP	thermocouple psychrometer
TGA	thermogravimetric analysis
TIP	Technical Implementing Procedure
TL	thermoluminescence
TM	Thematic Mapper
TPT	Testing Prioritization Plan
TSR	Technical Status Report
UNE	underground nuclear explosion
UNLV	University of Nevada/Las Vegas
USBR	U.S. Bureau of Reclamation
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
UZ	unsaturated zone
VLF	very low frequency
VSP	vertical seismic profiling
WRSOP	White River Shale Oil Project
WSNSO	Weather Service Nuclear Support Office
WT	water-table
WVDP	West Valley Demonstration Project
XRD	x-ray diffraction
XRF	x-ray fluorescence

PROGRESS REPORT ON SITE CHARACTERIZATION: YUCCA MOUNTAIN, NEVADA

April 1, 1990 - September 30, 1990

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