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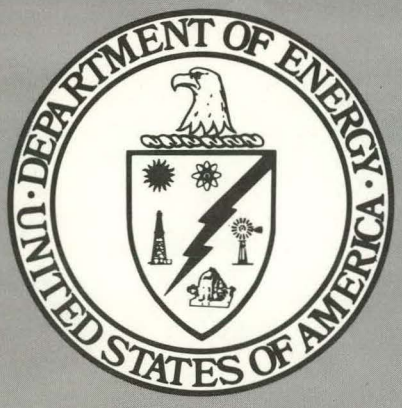

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NEVADA NUCLEAR WASTE STORAGE INVESTIGATIONS

Quarterly Report for April–June 1982

September 1982

United States Department of Energy
Nevada Operations Office
Las Vegas, Nevada

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INTRODUCTION

The U.S. Department of Energy (DOE) is responsible for finding and qualifying potential repository sites and developing the technology for safely and permanently containing and isolating radioactive wastes from the biosphere. The purpose of the DOE National Waste Terminal Storage (NWTS) Program is to safely dispose of spent reactor fuel and the high-level and transuranic wastes associated with commercial nuclear reactor fuel cycles.

The Nevada Nulcear Waste Storage Investigations (NNWSI), which are a part of the NWTS program, are studying the Nevada Test Site (NTS) area to establish whether it would qualify as a licensable location for a commercial nuclear waste repository; determining whether specific underground rock masses in the NTS area are technically acceptable for permanently disposing of highly radioactive solid wates; and developing and demonstrating the capability to safely handle and store commercial spent reactor fuel and high-level waste. In addition to its arid climate and remoteness from populated areas, the NTS area is of interest for the storage and ultimate disposal of radioactive waste for three principal reasons:

-- Present knowledge about the geologic and hydrologic conditions at the NTS and in the surrounding region indicates that the overall conditions are favorable for finding a licensable site for a mined, underground resposi-tory somewhere in the NTS area which will be capable of permanently isolating highly radioactive wastes from the biosphere.

-- The NTS and adjacent lands are controlled by the federal government and already require long-term monitoring and administrative control due to past and ongoing nuclear activities.

-- A strong base of logistical support already exists at the NTS which can be readily and economically augmented to support extensive exploration work and the development and management of a nuclear waste repository should an acceptable site be identified and qualified.

The NNWSI are being managed by the DOE Nevada Operations Office (NV). The principal NNWSI Project participants are: Los Alamos National Laboratory (LANL), Lawrence Livermore National Laboratory (LLNL), Sandia National Laboratories (SNL), Westinghouse Electric Corporation (WEC), and the U.S. Geological Survey (USGS). The principal participants occasionally engage subcontractors to perform part of their research work. They also conduct some of their work using the NTS support contractors. The NNWSI organization chart is shown in Figure 1.

This document is a compilation of the technical progress of the principal NNWSI participants in meeting the objectives described in the draft FY 1982 NNWSI Project Plan and revised planning documentation during the third quarter of FY 1982. The NNWSI Project Work Breakdown Structure (WBS) for FY 1982 is comprised of eight tasks which form the main sections of this document.

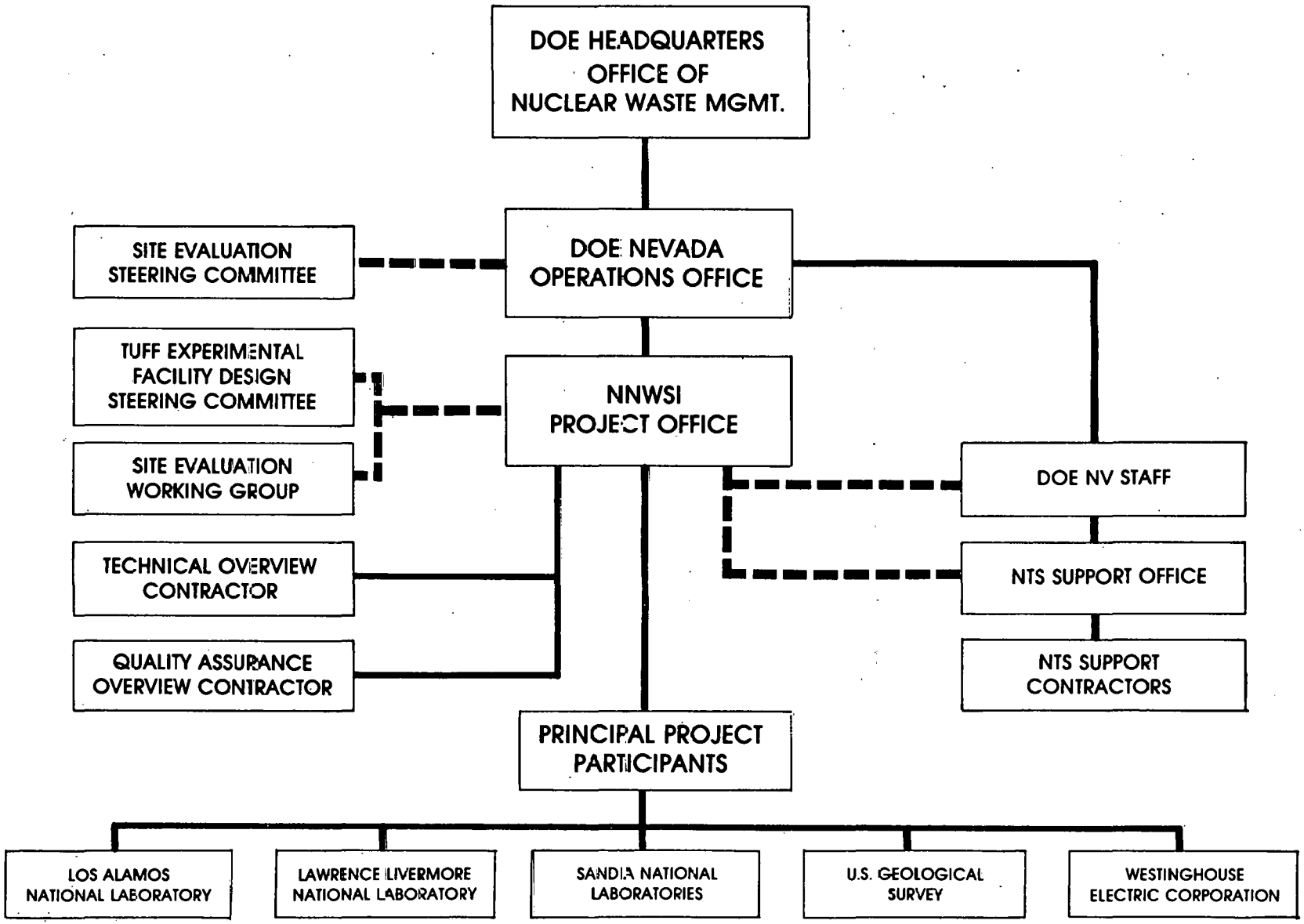

Figure 1. NNWSI Organization Chart

HIGHLIGHTS

-- A code library was established to provide a central location for documentation of repository performance assessment codes.

-- A two-dimensional finite element code, SAGUARO, was developed for modeling saturated/unsaturated groundwater flow.

-- The results of an initial experiment to determine canister penetration rates due to corrosion indicate the expected strong effect of oxic environmental conditions on the corrosion rate of carbon steel in tuff-conditioned water; alloy steels containing chromium and molybdenum exhibited significantly lower corrosion rates under the same conditions.

-- Wells USW-H3 and USW-H4 at Yucca Mountain have been sampled for groundwater analysis.

-- A study of natural geothermal sites in felsic tuffs like those at Yucca Mountain was begun to provide information on the long-term behavior of such tuffs in the near-field thermal gradient of a waste repository.

-- A summary characterizing and relating the mineralogy and petrology of Yucca Mountain tuffs was compiled from the findings of studies of core samples from five drill holes.

-- Quantitative interpretations do not support previous qualitative interpretations that a large intrusive rock mass similar to the Climax stock is present at shallow depth beneath Calico Hills. Recent studies indicate that most of the geophysical anomalies observed arise from strongly magnetized argillite, rather than intrusive rock.

-- Hydrologic wells USW-H4 and USW-H5 were drilled to depths of 1,219.2 meters. Hydrologic testing was completed in USW-H4; the static water level is similar to other nearby wells.

-- The trenching of alluvium near faults has been completed on the east side of Yucca Mountain. Mapping of the trenches has been completed; no displacement of alluvium has been found.

-- Two earthquakes of particular interest (M_L 3.5) occurred in Death Valley in an area of youthful deformation where Quaternary gravels are folded and tilted. These moderate-sized earthquakes are typical of those occurring, not on the major Death Valley-Furnace Creek system, but on subsidiary faults in the Salt Creek Hills.

-- The Hawaiite-type lavas which erupted next to Yucca Mountain at Crater Flat were found to form a "straddling" alkalic series in which the less evolved basalts plot near the normative olivine-diopside divide and the more evolved basalts project into the hypersthene or nepheline fields.

-- The rise rate of basaltic magma for the strombolian volcanic centers in Crater Flat was probably in the low range of typical basaltic rise rates based on ratios of cone volume to lava volume and short lava lengths. Potential dispersal pathways of radioactive waste incorporated and dispersed through stromblian eruptions were traced to predict the consequences of such an eventuality.

-- No new volcanic units were found as a result of analysis of drill hole USW-VH1 in Crater Flat; however, analyses provided important evidence on the structure and possible Miocene caldera locations just west of Yucca Mountain.

-- Geochronologic analytical results indicate that the source for the oxygen in NTS calcites is meteoric water. The source for the carbon in nearby Amargosa Desert samples was found to be dissolved atmospheric carbon-dioxide and Precambrian carbonates as reflected by the near-zero values of their carbon isotopic compositions.

-- A specially designed seismicity monitoring canister was installed at 1,850 feet in depth in drill hole USW-G1 at Yucca Mountain.

-- The first creep test was performed with tuff from drill hole USW-G1 at Yucca Mountain; sudden tertiary creep failure occurred at 69 hours.

-- The first phase of the Small-Diameter Heater Experiment in unsaturated welded tuff was completed; this experiment is obtaining data on groundwater migration in tuff subjected to localized heat. The results support the interpretation that groundwater does initially migrate toward the heater hole and then vaporizes; the water vapor that collected in the hole appeared to migrate toward the cooler area above the heater and no water collected in the bottom of the hole during cooldown.

-- Results for the Yucca Mountain tuffs tested indicate that there is a consistent temperature effect on the dehydrated thermal conductivity of zeolitized tuffs.

-- Testing of the thermal expansion of zeolitized tuff was completed; the results appear to be consistent and correlated with broad trends in mineralogical variations with depth.

-- Four of the replacement potentiometers on the vertical extensometers for the Spent Fuel Test--Climax failed. The problem appears to be localized in the head assemblies which are sealed to maintain the ambient environment of the extensometer.

-- The ventilation effects tests using the Spent Fuel Test--Climax Facility were started and heat removal and other data are being acquired.

-- Activities in support of the Exploratory Shaft are proceeding on the basis that shaft construction will start in March 1983.

-- Activities in support of the Test and Evaluation Facility were terminated by DOE/HQ on April 9, 1982.

-- All of the E-MAD Near-Surface Storage Test drywells were opened to remove fueled canisters for gas sampling. While the drywells were open, it was observed that moisture was collecting in the liners.

-- A quality assurance procedure is being developed for reporting nonconformances during drilling activities.

WORK BREAKDOWN STRUCTURE

1.1 SYSTEMS

Objective: To plan, document, and evaluate the performance of the Project and to identify modeling techniques to evaluate the performance of the overall waste package, site, and the repository containment and isolation systems.

1.1.1 PROGRAM BASELINE

Objective: To evaluate the performance of the Project.

The TPOs and the TOC worked with the Project Manager, LANL, LLNL, SNL, USGS, WEC, contractors, and subcontractors in planning, coordinating, reviewing, documenting, and implementing a balanced technical project. This activity has no reportable progress.

1.1.2 SYSTEMS ANALYSIS

(No NNWSI work funded this fiscal year.)

1.1.3 SOCIOECONOMIC ASSESSMENT

(No NNWSI work funded this fiscal year.)

1.1.4 ALTERNATE DISPOSAL CONCEPTS

(No NNWSI work funded this fiscal year.)

1.1.5 PERFORMANCE ASSESSMENT

Objective: To assess the performance of the overall waste containment and isolation systems.

Program planning extending through performance assessment contributions to the NNWSI license application documents (EIS, PSAR) was completed this quarter. Analyses are to proceed in two steps. The first, Phase I, exercises the analysis techniques with the data on hand and sets the stage for the second phase. The second phase uses data and codes available four months before the DEIS input is due. Codes to be used must be working as of that date with all verification activities and preliminary validation completed. Phase II calculations will be included in license application documents.

A letter report of the modeling needs for performance assessment was sent to NV. The report described the nature of the performance modeling to be done by December 1983, the computer codes to be used (where known), and the data needed. The letter report satisfied the milestone due at DOE/NV at the end of June 1982 for Task 1.1.5, Performance Assessment. The codes FEMWATER, FEMWASTE, and SAGUARO were identified for Phase I near- and far-field geosphere hydrologic and radionuclide transport calculations. The three codes

are running at SNL and are compatible. A biosphere transport dose-to-man code has not yet been selected. The waste package subsystem performance assessment code, WAPPA, was received from Intera Environmental Consultants, Inc. A copy of the documentation and tape were sent to LLNL. The model is currently being reviewed before integrating it into the overall performance assessment activity.

The revised draft of the "Preliminary Technical Performance Constraints for a Repository in Tuff," compiled by J. K. Johnstone (SNL) and P. Gnirk (RE/SPEC), was completed and submitted to DOE/NV. The draft incorporates changes and comments of reviewers at SNL, LLNL, LANL, and RE/SPEC.

Another June 1982 milestone for the Performance Assessment task was completed on schedule. The milestone was met by a letter report to DOE/NV on the derivation of partially saturated flow equations to be used in the Consequence Analysis task.

Two invited abstracts, "System Study and Performance Constraints for Repository Horizon Selection at the Nevada Test Site," by J. K. Johnstone, R. R. Peters, and A. R. Lappin; and "Performance Assessment in the Nevada Nuclear Waste Storage Investigations," by L. D. Tyler, J. P. Brannen, B. S. Langkopf, and N. K. Hayden, were submitted to the American Nuclear Society for the 1982 Winter Meeting.

Isolation System

The report "Preliminary Scenarios for Consequence Assessments of Radioactive Waste Repositories at the Nevada Test Site" (SAND82-0426), was submitted to DOE/NV on April 19, 1982. This submission completed a March 1982 milestone, Far-Field Breaching Scenario Draft Report.

Substantial progress has been made this quarter on a report similar to SAND82-0426 that will address only the far-field breaching scenarios that apply to tuff at Yucca Mountain. The report will contain detailed recommendations for consequence modeling of releases from a Yucca Mountain repository.

Repository Systems Performance Evaluation

Consequence Analysis--The Consequence Analysis for NNWSI Performance Assessment will follow the outline shown below. Analyses of these processes, in both the saturated and unsaturated zones, will cover all significant release events and pathways identified for Yucca Mountain by scenario analysis (SAND82-0426).

a. Groundwater Carries Waste:

    1. Normal flow through existing pore/fracture system.

    2. Flow through altered system.

        -- Change of fracture system.

-- Change of head gradient.

-- Establishment of direct communication of flow with a biosphere entry point.

3. Transient flood in repository.

b. Direct Exposure to Waste:

1. Drilling.

2. Volcanism (completed study).

"Consequence of Basaltic Volcanism Through a High-Level Waste Repository," an invited abstract by R. L. Hunter and S. E. Logan, was submitted to the American Nuclear Society for the 1982 Winter Meeting.

PNL, under the direction of SNL, has begun the development of a two-dimensional groundwater flow model that roughly encompasses Yucca Mountain, Crater Flat, western Jackass Flats, and parts of the Amargosa Valley. Boundary conditions for the model have been matched to the USGS regional model, and the water table also was compared to USGS interpretations. Flow lines, transmissivities, and travel times have been calculated. The groundwater model will be used in consequence analysis of possible waste releases from a repository.

Code Acquisition and Validation

An activity for the acquisition, development, and validation of computer codes to be used in performance assessment modeling has been initiated. The goals of the activity are:

Code Library--A code library within the Performance Assessment Division was established. Its purpose is to provide a central location for documentation of performance assessment codes which may be of interest, as well as those which have already been used. Documentation for the SCEPTER program is being reviewed and entered into the library as it is received from Intera. Six codes are of particular interest: WAPPA, PABLM, DACRIN, MMT, VERTPAK-1, and FTRANS. In addition to SNL internal codes and SCEPTER, a file of abstracts from ONWI-78 for unsaturated groundwater and radionuclide transport codes has been formed. Contacts were made with the National Energy Software Center (NESC) at ANL and the Radiation Shielding Information Center (RSIC) at ORNL to help identify documentation sources.

Code Acquisition--Codes acquired to date are WAPPA, PABLM, PHR81, FEMWATER, and FEMWASTE. A package of analytic solutions for various flow and transport models has been requested of ONWI.

Development--A two-dimensional finite element code, SAGUARO, for saturated/unsaturated flow was developed at SNL and is in the process of being documented. It is related to FEMWATER and can also be coupled to FEMWASTE.

It is not isothermal and could be useful for those postemplacement analyses for times at which the system's thermal loading from young waste is important. A report on the equations coded in SAGUARO and proposed additions to the code to account for water vapor effects were submitted to DOE/NV.

Validation--The goals of validation have been identified as: (1) assurance of adequacy of documentation, (2) assurance of code verification, and (3) demonstration of model validity shown by consistency with and/or acceptable prediction of laboratory tests, field data, or natural analogues. The code library should achieve the first goal. A plan for achieving the second and third goals is being developed. Code verification will be achieved by comparing code output to analytic solutions, if possible, and to other well-established codes where analytic solutions do not exist. The demonstration of model validity requires further delineation and quantitative definition. Quantification will require parametric studies for the physical processes being modeled. An outline for the validation process of thermomechanical analyses done in support of Performance Assessment has been drafted. The outline focuses on validation of the predictions of in situ permeability changes due to mechanical response of the rock to thermal loading. The current suggested data sets to be used for comparison are those from the Eleana Heater Test, STRIPA data, BWIP data, and/or a block test.

1.2 WASTE PACKAGE

Objective: To integrate the development of a waste package for tuff with the NWTS Program and to design, construct, and qualify waste packages which allow for the safe handling, storage, and containment of the waste and which permit safe retrieval of the waste package, i.e., everything placed into the repository emplacement hole.

1.2.1 WASTE PACKAGE BASELINE

(No NNWSI work funded this fiscal year.)

1.2.2 WASTE FORM

(No NNWSI work funded this fiscal year.)

1.2.3 BARRIER MATERIALS

(No NNWSI work funded this fiscal year.)

1.2.4 DESIGN AND DEVELOPMENT

Objective: To provide design drawings and specifications for waste package components and to develop package fabrication equipment specifications.

1.2.4.1 Tuff Waste Package Development

Objective: To integrate the development of a waste package for tuff with the NWTS Program for emplacement in a repository on or near the NTS.

Additional personnel added to the WP task group on a part-time basis include R. Van Konynenburg (Nuclear Chemistry), D. Vreeland and R. Pierce (Mechanical Engineering Thermal Fluids Group), K. Keller (Nuclear Test Engineering), and J. Younker (Earth Sciences Department).

Experimental Work on Yucca Mountain Tuff

An additional 400 pounds of tuff from the Bullfrog Member of the Crater Flat Tuff were collected. These samples were larger blocks of sufficient size to produce intact, oriented 3-inch cores suitable for the permeability measurements to be made by the USGS, Menlo Park. The material was collected from the same outcrop sampled during the second quarter of FY 1982 (the thick section of Bullfrog Member north of Lathrop Wells). The bulk of the rock will be sent to the USGS, although LLNL will retain a portion for experimental purposes (see below) and historical samples.

A 4-kg sample of Bullfrog Member Tuff was prepared for use in metal corrosion tests being carried out at LLNL; samples for thermal conductivity measurements were also prepared. Also, about 4 kg of Bullfrog Member Tuff was pulverized to -100 mesh using a tungsten carbide mill; this material will be used to make

preliminary mechanical/physical property measurements and for fabrication (pressing) tests. Since tungsten carbide has a potential for contaminating the rock sample with Ta, Co, Nb, Ti, and W, for the projected hydrothermal experiments, an additional 3 kg of -100 mesh material was prepared using the clean alumina flat plate grinders at the USGS, Menlo Park.

Representative aliquots from tuff samples of -100 mesh Bullfrog Member powder were analyzed by INAA (neutron activation). Complete XRD analysis of this material has shown only trace amounts of mixed-layer (illite-montmorillonite) clay. Evidence for the presence of zeolites in the sampled outcrop of Bullfrog Member Tuff was looked for, but none was detected. Hence, it was concluded that this partly welded, vapor-phase altered material was not zeolitized.

Grain mounts of the crushed material have been prepared for SEM/microprobe analyses to be used as reference samples for the detection of hydrothermal alteration in experiments that are now being conducted.

The quantitative microprobe analyses and petrographic examination of thin sections from the Bullfrog Member outcrop are nearly complete. To date, 53 analyses have been made for biotite, amphibole (hornblende), and feldspars previously identified in this section. Photomicrographs were made of all mineral grains analyzed. This work is done to characterize and relate the outcrop material used for laboratory tests to the smaller core samples done previously.

Thin sections of densely welded, nonzeolitized Topopah Spring Member tuff are now being made.

A sensitive (20 ppb) calorimetric method for Si analyses has been successfully tested using the Technicon autoanalyzer. This method will be used under conditions (high total dissolved solids, high sodium) where ICP-OES cannot provide reliable results.

Backfill Developmental and Experimental Work

Fabrication of Candidate Backfill Materials--One of the designs proposed by Westinghouse for disposal of spent fuel involves the use of bentonite inside the metal overpack material. This design will be referred to as the "self-contained" waste package. In order to investigate the stability of bentonite under conditions likely to be encountered in a self-contained package, a number of samples of bentonite (Wyoming Volclay MX-80) and bentonite plus sand or tuff mixtures were fabricated. These samples will be dehydrated at 250°C and then encapsulated in stainless steel. The sealed samples will be tested over a range of temperatures to determine the stability of bentonite under conditions which are expected during the early high-temperature period of repository storage.

Work has begun on the fabrication of crushed tuff for evaluation as a backfill material. Initial uniaxial pressing attempts on material crushed to less than 100 mesh (see above) resulted in samples which were somewhat friable. Use of

a coarser tuff as starting material and use of additives such as a small proportion of clay minerals are being investigated to see whether this results in better quality samples.

Permeability Experiments--A contract was established with the USGS, Menlo Park, to measure the permeability of tuff samples in a temperature gradient. Work will involve use of a central heater which produces a maximum temperature of about 300°C. Samples will be taken of fluids which are passed through the tuff during the permeability measurements. These fluids will be studied for chemical changes due to reaction with the tuff. After measurements are completed, the cores of tuff will be examined to determine the extent of alteration in the tuff minerals. The results of this experiment will be compared with future experiments on cores of backfill materials based on tuff.

Tuff/Water Interactions--An experimental program was initiated to study the hydrothermal reactions of the Bullfrog tuff. A representative sample of tuff was crushed to less than 100 mesh. Portions of this sample were then reacted with J-13 water at 150°C in Teflon capsules. The amount of water used was kept constant (12 g), and the amount of solid used was varied to provide an indication of the approach to saturation in the solutions after reaction. Sample weights used were 0.1, 0.2, 0.4, 0.8, and 1.2 grams. Runs of samples at each weight are conducted for 1, 2, 4, 8, 12, 16, 24, 32, and 48 days. The reacted water is separated into two portions, one of which is filtered through a 0.1-micron filter. Preliminary results are available for cation analyses of all weights for 1 and 4 days of reaction for both filtered and unfiltered solutions. Unfiltered samples are always higher in Al and Fe than filtered samples, while Ca, Na, and K are the same in filtered and unfiltered solutions. This suggests that Al and Fe are present as small particles in the water and are not truly in solution. Concentrations of Si are the same in filtered and unfiltered samples except for the 1.2-gram runs which show somewhat higher Si in the unfiltered samples. This suggests that the Fe and Al particles are not small pieces of tuff minerals, but rather hydroxides which are slowly precipitating from the reacted solutions.

Changes in water chemistry which are observed are:

Si: Increases rapidly from 28 ppm for water heated alone at 150°C to 95 ppm for 0.1 gram of rock reacted for 1 day. Increase in silica for further reaction is slow, with the highest value being 163 ppm for 1.2 gram of tuff reacted for 4 days.

Al: Initial increase to 1.3 ppm for 0.1-gram sample at 1 day, followed by decreasing concentrations, with the lowest values occurring for largest samples after a 4-day reaction time.

Fe: For filtered solutions, Fe is always low (less than 0.05 ppm in all cases).

Na: Small samples (0.1, 0.2, and 0.4 gram) average 60 ppm for 1 and 4 days of reaction. Larger samples (0.8 and 1.2 gram) average about 100 ppm. The reason for this difference is not presently understood.

Ca: Decreases from early values of about 9 ppm to values of about 5 ppm for all samples at 4-day reaction time. Larger samples show 5 ppm Ca even after 1 day of reaction.

K: Results are somewhat variable; most samples show an initial increase to 10 to 12 ppm followed by a lower concentration for samples with longer reaction time. Lowest values found were 6 ppm for the 0.1-gram sample after 12 days of reaction.

Metallic Barrier Materials: Preliminary Corrosion Testing

The results of an initial corrosion experiment indicate the expected strong effect of oxic environmental conditions on the corrosion rate of carbon steel in tuff-conditioned water. Corrosion penetration rates were up to 500 times greater in air- and oxygen-saturated water than in nitrogen-saturated water. Alloy steels containing chromium and molybdenum exhibited significantly lower corrosion rates than that of carbon steel in the oxic environments.

The purpose of the experiment was to determine the range of corrosion penetration rates which may be encountered in groundwater as a function of the oxidizing potential Eh of water. Different oxidizing potentials were obtained by bubbling gases through the water. The dissolved oxygen content, in particular, is related to the corrosion rate of steel in near-neutral pH solutions, where the reduction of oxygen-to-water balances the oxidation of iron to ferrous and ferric compounds.

The experiments were conducted at 80°C and ambient pressure. At this temperature, the decreasing solubility of oxygen is countered by the increasing diffusion rate of oxygen to the steel surface so that the resulting corrosion rate tends to a maximum. Further, the steel surface is less protected by precipitation (scaling) of sparingly soluble compounds at this temperature because of the retrograde solubility of many of these compounds.

Five test cells were used for conducting the corrosion experiment. Crushed Bullfrog Member tuff (average particle size of 5 mm) was placed in a small perforated container in each cell. Deionized water was used for the makeup with a volume ratio of 5 parts water to 1 part of crushed tuff. The water was conditioned by the tuff for 10 days before the corrosion coupons were immersed. Analytical samples were withdrawn for determining the concentration of chemical species leached from the tuff. Three coupons of each of the three steels were immersed in the tuff-conditioned water. The coupons were previously weighed and were of a size approximately 2 inches long by 1 inch wide by 1/8-inch thick. They were suspended in a vertical position by nylon fasteners and kept isolated from one another. The three steels tested were a carbon steel (AISI 1018) and two alloy steels (2 1/4 Cr-1 Mo designated ASTM A387 Grade 22 and 9 Cr-1 Mo designated ASTM A387 Grade 9).

In the first cell, the tuff-conditioned water was in contact with air and no gases were bubbled through this cell. In the second cell, compressed air was bubbled through; in the third, oxygen; the fourth, nitrogen; and the fifth, carbon dioxide.

The experiment lasted 1,344 hours. Samples of the water containing dissolved corrosion products and ionic species leached from the tuff were withdrawn periodically from the cells for analysis. A sixth cell, with no corrosion coupons emplaced inside, was operated at 80°C to determine the leaching rate of Bullfrog Member tuff without the presence of the corrosion products.

The exposed coupons were cleaned of corrosion and scale products according to the ASTM G-1 test procedure. Each coupon was then weighed and the weight loss during the exposure period was calculated and converted into a corrosion penetration rate. The specimens which experienced the higher corrosion rates were covered by insoluble corrosion products over much of their surface area, while the specimens which experienced low corrosion rates showed only a light tarnishing.

In addition to the corrosion rates reported above, several of the carbon steel and 2 1/4 Cr-1 Mo alloy steel coupons suffered localized attack in areas that were covered by scale and insoluble corrosion products. The depth of these attacked areas is on the order of 10 mils, which would translate to an additional penetration rate of 150 micrometers/year. The depth of this localized attack is being quantified, but this preliminary observation suggests that the corrosion resistance of many ferrous materials in oxic conditions in tuff groundwater may not be sufficient to withstand the requirements of a 1,000-year container life. Other tests must be performed, of course, particularly at the higher temperatures. This experiment does demonstrate the wide differences in behavior between oxic (air- and oxygen-saturated solution) and anoxic (nitrogen-saturated solution) conditions as regards the corrosion behavior. Siting the repository where the dissolved oxygen content in the groundwater is low would obviously be advantageous to steel as an overpack material. The high-alloy steel (9 Cr-1 Mo) did perform consistently better than the other steels tested, and this material may indicate the alternatives if oxidizing conditions prevail. Future work will be directed toward determining the corrosion rates of different steels and cast irons over the range of temperatures and oxidizing conditions that may be obtained in the repository environment.

The reason for the pH increase during the corrosion experiment in some of the cells is not known. The same result was obtained by several different pH measurements. Apparently, this change is not related to the formation of corrosion products, as the pH change is nearly the same for the nitrogen-saturated cell as the oxygen- and air-saturated cells. The pH decrease in the CO_2-saturated cell is expected, although it appears that the CO_2-saturated water is caused by the addition of another reduction reaction, viz., the reduction of water to form hydrogen gas.

A detailed report on this preliminary experiment and its implications on future testing is in preparation.

Modeling/Performance Assessment

Documentation was received from Intera Environmental Consultants for the WAPPA Code: A Waste Package Performance Assessment Model. A review of this documentation was initiated to determine the applicability of the subsystem models

to waste package siting conditions specific to tuff. An initial attempt to implement the WAPPA code on the LLNL 7600 computer system was unsuccessful due to a limitation of available memory. However, arrangements have been made to bring the code up on the LBL 7600 system. This alternative will permit a limited number of test problems to be run as part of the code evaluation. Pending the results of this study, a decision will be made regarding the conversion of WAPPA to the LLNL Cray system.

Site Characterization Report

Draft inputs to Chapters 9 and 10 (formerly 10 and 11) of the Site Characterization Report were completed and forwarded to SNL, Albuquerque.

Documents Reviewed

-- The ONI departure point document, NWTS Generic Waste Disposal System Description, was reviewed; the initial draft of this document has now been received and a detailed review of Chapter 3 (The Waste Package System) is in progress.

-- BWIP SCR Draft of Chapter 15.

-- Draft AESD-TME-3131 (Westinghouse AESD salt WP design document).

-- NUREG-0856 (code documentation).

Documents Prepared

-- Site Characterization Report, Chapter 10, Sections 10.1 (entire), 10.3.1, 10.3.2.1 (all parts), 10.3.2.2.2 and 10.3.2.3.

-- Leach Testing of Waste Forms--Interrelationship of ISO and MCC Type Tests, V. M. Oversby, UCRL-87621. Paper presented at Workshop on Leaching Mechanisms, Gaithersburg, Maryland, May 19-21, 1982.

1.3 SITE

Objective: To characterize the southwest NTS area to identify and technically qualify a possible site for the construction and operation of a mined geologic repository for radioactive waste.

1.3.1 SITE BASELINE

Objective: To establish the requirements for conducting the Site task and to ensure that the objective of the Site task will be met.

This task has no reportable progress.

1.3.2 EARTH SCIENCES

Objective: To develop the data base and methodology necessary to characterize the geologic system and understand its physical-chemical interactions.

1.3.2.1 Nuclide Migration Field Experiments

Objective: To develop the experimental, instrumental, and safety techniques necessary to conduct controlled small-scale, at-depth nuclide migration experiments in the field.

1.3.2.1.1 Nuclide Migration Field Experiments in Tuff

Objective: To develop and use in situ nuclide migration assessment techniques in tuffaceous media in order to develop a predictive capability for field conditions.

Field Site

The feasibility of constructing an adit near the Yucca Mountain exploration block is being investigated. The proposed adit is relatively shallow (about 200 feet), but it would permit the performance of field experiments in tuff that is both unsaturated and similar to the geologic material in the exploration block. Six outcroppings of tuff were surveyed to select a possible site for the adit. Four of the outcroppings exposed the Topopah Spring Member, and the remainder exposed bedded tuffs of Calico Hills. One of the four Topopah Spring Member sites was selected for detailed surveying and horizontal coring. The first draft of criteria for the horizontal coring was prepared. Analyses of the cores will provide data for the next step in the site selection process for this adit.

The most promising site for an adit in the bedded tuffs of Calico Hills is located in the Prow Pass area. The outcropping is outside the current U.S. Air Force use-permit area. The area has been found to contain archaeological ruins. The time required to renegotiate the use permit and to prepare and implement an archaeological impact mitigation plan is estimated to be at least six months. A delay of this length would adversely affect the timeliness of

data from an adit at this location for the Yucca Mountain repository horizon selection process.

The Grouse Canyon tuff in G-Tunnel was inspected this quarter as a potential site for a radionuclide migration field experiment, should the adit in the unsaturated tuff prove to be infeasible for this work.

An engineering investigation has been initiated to determine the status of test equipment and designs available at Lawrence Livermore National Laboratory and Sandia National Laboratories for conducting radionuclide migration studies in the field.

Development and Characterization of Groundwater Tracers

Additional preliminary investigations were made to separate and detect salts of fluorinated benzoic acids by high-performance liquid chromatography (HPLC). Sodium salt solutions were made of six fluorinated benzoic acids by adding an equivalent amount of 0.01 M NaOH to a weighed portion of acid to achieve an approximate final concentration of 800 to 850 mg/l salt. Ultraviolet spectra of the salt solutions were obtained in an attempt to determine the optimum wavelength for monitoring HPLC separations. A wavelength that would provide strong absorbance for all compounds of interest, yet be free of interferences from matrix components, etc., would be advantageous.

The salts were run individually by HPLC, using a C18 column and a mobile phase mixture of methanol, water, and phosphate buffer (pH 5.5) prepared by adding 0.1 M K_2HPO_4 (initial pH 9.2) to a 0.1 M solution of KH_2PO_4 (initial pH 4.48) to achieve a final solution with the desired pH of 5.5. A wavelength of 225 nm was chosen to monitor the HPLC relation. Individual retention times for the salts were obtained; then separation of a mixture of all six salts plus a "parent" salt of commercially prepared, nonfluorinated sodium benzoate was attempted. Unfortunately, under the conditions used, two of the salts had nearly identical retention times and were not adequately resolved from the component mixture. The retention times of the individual salts do not seem to correlate with the measured pK_a values, nor are they necessarily expected to.

Ultraviolet spectra were obtained for solutions of nitrate, nitrite, and water from Well J-13. Nitrate species were reported to interfere with detection of the tracers,* and it was thought that components of Well J-13 water might also interfere; therefore, a set of spectra of such background matrix components seemed advisable. The spectra indicated possible significant interference only in the wavelength region below 210 nm and probably only at low tracer concentrations.

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*From information supplied to K. Wolfsberg by the Department of Hydrology, University of Arizona, Tucson, Arizona.

Further studies are planned to optimize the monitor wavelength, using a Spectra-Physics wavelength scanning program, and to determine sensitivity limits and matrix effects encountered in a field test situation.

1.3.2.1.2 Nuclide Migration Field Experiments in Granite

Objective: To develop in situ nuclide migration assessment techniques in the granitic media of the Climax facility.

In accordance with the project termination plan, our effort this quarter was spent on documenting previous work. The following three reports, including the final published version of the Engineering Test Plan, were sent to NV for review this quarter:

-- Engineering Test Plan for Field Radionuclide Migration Experiments in Climax Granite, D. Isherwood et al., UCRL-53286.

-- The Design and Fabrication of Apparatus for In Situ Hydraulic Testing of Fractured Rock, E. Raber, D. Lord, and P. Burklund, UCID-19405.

-- Laboratory Studies of Radionuclide Transport in Fractured Climax Granite, R. Failor, D. Isherwood, E. Raber, and T. Vandergraaf (to be published as a formal LLNL report).

The following report is in preparation and will be completed this quarter:

-- Climax Granite Groundwater Characterization Study, D. Isherwood, J. Harrar, and E. Raber (to be published as a formal LLNL report).

Meetings Attended

-- AECL's Geochemistry Information Meeting, Winnipeg, May 26-27, 1982 (D. Isherwoodd and T. Wolery).

-- Materials Research Society's Program Committee meeting to review papers submitted to the 1982 Scientific Basis for Nuclear Waste Management Symposium, Albuquerque, June 23-24, 1982 (D. Isherwood).

1.3.2.2. Tuff Studies

Objective: To determine the geochemical, mineralogical, and petrological properties of tuff.

1.3.2.2.1 Geochemistry

Objective: To determine the geochemical properties of tuff and the geochemical environment in Yucca Mountain as a basis for predicting the migration of radionuclides to the accessible environment and for assessing the response of potential repository sites in Yucca Mountain to a repository environment.

Groundwater Chemistry

Wells USW-H3 and USW-H4 at Yucca Mountain have been sampled for chemical analysis. Well USW-H3 was not producing a sufficient amount of water and was not pumped. Therefore, the samples for analysis were taken by swabbing prior to the injection testing of the well. The high chloride content (35 mg/l), high lithium content (2.6 mg/l), and the high detergent content of the water, all of which were introduced during the drilling, indicate that analyses of samples from unpumped wells are not representative of natural geochemical conditions. The high content of suspended $Fe(OH)_3$ and black rubber particles in the water shows also that swab samples are not usable samples. The $Fe(OH)_3$ is known to be a good adsorber and precipitating agent for other cations. Well USW-H4, however, was pumped for approximately nine days; the results of analyses of water at the end of the pumping period were obtained. These samples were anaerobically collected, filtered through a 0.05-micrometer Nuclepore membrane, and then sent to Los Alamos for chemical analysis. The electrode measurements were made in the field. The results must be used with caution. Although pumping duration was nine days, the water exiting the pump continued to foam; obviously the water still contained detergent from the drilling of the well and was not pure formation water. After the pump had been stopped and removed from the well, at-depth samples were taken at selected intervals using evacuated stainless steel bottles. The analytical results on these samples, when completed, will serve as baseline compositions for any further pumping and analyses of the water from this well.

A program for the testing of a single stratum of Well UE25b-1 was set up and implementation was started in June. Of primary concern in the determination of the chemistry of the groundwater is knowing when the water is formation water, free from any of the drilling fluids. The main components of fluids used in the drilling of hydrology wells are Well J-13 water, air, and detergent. Lithium chloride is also added to serve as a tracer for the water used as drilling fluid. It is especially important to eliminate all drilling fluids because the oxygen concentration of the groundwater is one of the most important variables in the chemistry of the water, affecting retardation mechanisms and corrosion of the waste package. Winograd and Robertson have suggested that groundwaters in the tuffs of Nevada may always contain dissolved oxygen. It seems reasonable that the flowing water, which may be the least influenced by oxygenated recharge water and by air in the unsaturated tuffs or fractured tuffs, will be the water in the deepest permeable zone.

The deepest permeable zone in Well UE25b-1 was determined previously by "tracejector" tests to be at 2,840 to 2,870 feet.* This zone is separated from other permeable zones above it by about 200 feet of more impermeable tuff; therefore, isolation of this permeable zone will be attempted with a bridge plug at 3,000 feet and a packer at 2,800 feet. The water from between

*Data supplied by the Nuclear Hydrology Group, U.S. Geological Survey, Denver, Colorado.

these packers will be pumped at a constant rate of about 200 gallons per minute until there are indications that formation water (maximum of 30 days at this time) is being obtained.

Periodically, samples will be taken anaerobically and analyzed. The Eh, pH, oxygen concentration, sulfide concentration, and temperature of the water will be measured several times a day using electrodes. Analyses of anions in anaerobically filtered (0.05-micrometer) samples will be made daily in the field for anion constituents, and acid-stabilized samples will be sent back to Los Alamos for cation analysis. Field analysis will also be made on the detergent content of the water to determine if the sulfonate ion in the detergent can be used as a measure of how well the water is being cleared of drilling fluids.

Solubility of Plutonium(IV) in Natural Waters With Carbonate Present

In natural waters that are not strongly oxidizing, soluble plutonium generally exists as Pu(IV). The solubility of Pu(IV) will depend on the activities of many of the species in the water. The influence of carbonate on Pu(IV) solubility is of particular interest here. Thermodynamic data exist for only one complex of Pu^{+4} with CO_3^{-2}. These data are based on the experiments of Moskvin and Gelman (hereafter referred to as MG), who measured the solubility of Pu(IV) in carbonate solutions in contact with $Pu(OH)_4(s)$.

The influence of K_1 on plutonium solubility can be seen from calculations of plutonium solubility in water that is typical of Well J-13 at Yucca Mountain. The total carbonate content of the water is 2.9×10^{-3} molal. Calculations of uranium and plutonium solubility as a function of solution Eh and pH were done with the EQ3 program. Both uranium and plutonium were assumed to be present. At a pH of less than 7, the plutonium solubility equals the carbonate content of the water. Under these conditions, essentially all the plutonium and carbonate exist as the $PuCO_3^{+2}$ complex. This is directly attributable to the stability of this complex, which is implicit in $\log_{10} K_1 = 40.7$. At high pH values, the plutonium solubility is below the total carbonate content, but it is still quite high because of the $PuCO_3^{+2}$ complex.

If the value of $\log_{10} K_1$ is as large as 40, this has significant implications for the waste disposal program. However, the experimental results of MG have been criticized as indicating that $PuCO_3^{+2}$ is much too stable. MG also measured formation constants for plutonium-oxalate complexes at the same time as the $PuCO_3^{+2}$ formation constant; their oxalate data are in agreement with other measurements indicating their technique was valid for the oxalate complexes.

The MG experiments involved measurements of total plutonium in solutions in contact with $Pu(OH)_4(s)$; the solutions had various carbonate concentrations from 0.36 to 3.6 M. Two groups of experiments were done. In the first, seven measurements were reported where the ionic strength was controlled (at approximately 7 and 10 M) and the pH was held at 11.5. The total plutonium in solution increased with increasing carbonate constant. In the second group of experiments, no attempt was made to control the ionic strength and the pH

varied from 9.7 to 11.6. For seven measurements, the total plutonium concentration first increased and then decreased with increasing carbonate content. From these measurements, MG reported $\log_{10} K_1 \cong 47$. Lemire and Tremaine have recently reviewed the MG experiments. Using revised data for the solubility of plutonium in contact with $Pu(OH)_4(s)$, they estimated $\log_{10} K_1 \leq 41$.

In analyzing their data, MG assumed that all the soluble plutonium was tied up in a single carbonate complex. Their data indicated a plutonium-to-carbonate ratio of 1, thus giving the $PuCO_3^{+2}$ complex. To assess this assumption and others inherent in the MG experiments, calculations of the solubility of plutonium under the conditions of the MG experiments were done with the EQ3 program. Only one Pu(IV) complex with carbonate is in the EQ3 data base, $PuCO_3^{+2}$ with $\log_{10} K_1 = 40.7$. The calculations were done for a solution Eh = 400 mV; the solution ionic strength was maintained at the experimental value by addition of potassium chloride. The calculated plutonium solubility is well above the measured results at the lower carbonate concentrations, but is in general agreement for the other cases. In addition to total calculated plutonium solubility, the concentrations of the two major aqueous plutonium species, $Pu(OH)_5^-$ and $PuCO_3^{+2}$ were determined. It is evident that the $Pu(OH)_5^-$ concentration is a factor of 10 to 100 greater than the $PuCO_3^{+2}$ concentration. Thus, one of the primary assumptions used by MG to calculated K_1 appears to be invalid. The high ionic strength of the solutions used by MG means that EQ3 is well outside the range where accurate activity coefficients are calculated. For this reason, the EQ3 results must be considered approximate.

The results were obtained form EQ3 calculations for the second group of experiments, in which the ionic strength was not controlled. Besides the varying ionic strength, the pH also varied among these experiments. Some difficulties were encountered in the calculation for the lowest carbonate (and lowest pH) case; a very large plutonium solubility (about 1~M) was indicated by results that did not converge. At the two lowest values of pH (9.7 and 10.6), the calculated plutonium solubility is much greater than the experimental results. Most of the aqueous plutonium is as $PuCO_3^{+2}$ at a pH of less than 11.25 because the Pu^{4+} concentration increases rapidly as the pH drops. This occurs because the Pu^{4+} concentration and OH^- concentration are related through the solubility of $Pu(OH)_4(s)$.

For the other five cases, the calculated plutonium solubility ranges from 1.3×10^{-3} to 1.9×10^{-3} molal; the measured plutonium solubility ranges from 1.3×10^{-3} to 12×10^{-3} M. The experimental results do not correlate well with total carbonate content or pH. The calculated results are primarily a function of pH and secondarily a function of carbonate content and ionic strength. As with the constant-ionic-strength group of experiments, the EQ3 calculations for this group indicate that a significant amount of the aqueous plutonium exists as $Pu(OH)_5^-$, particularly at higher values of pH. Thus, these calculations also indicate that one of the primary assumptions employed by MG may not be valid.

The fact that most of the soluble plutonium is tied up as $Pu(OH)_5^-$ under the conditions of the MG experiments indicates that their calculation would overestimate the stability constant of $PuCO_3^{+2}$ (their estimate of $\log_{10} K_1$ would

be too large). This conclusion is the same as previous criticism of the MG experiment. Because of this potential problem with the formation constant of $PuCO_3^{+2}$, an independent estimate of K_1 is pursued in the next section.

An Independent Estimate of K_1--Although experimental thermodynamic data are preferable to data estimates, data estimation techniques are often useful for testing the consistency of groups of data for similar species. One technique that has been used with actinides is a plot of formation constants for various aqueous complexes as a function of the number of ligands in the complex. If it is assumed that U^{+4} and Pu^{+4} form carbonate complexes of similar stability, the $U(CO_3)_5^{-6}$ result (n = 5) can be extrapolated, parallel to the lines for the other ligands, to n = 1. This gives $\log_{10} K_1 \cong 10$ as an estimate of the formation constant of $PuCO_3^{+2}$ that is consistent with the other actinide aqueous-complex data.

Calculations for the conditions of the MG experiments were rerun with EQ3 using $\log_{10} K_1 = 9.9$. For the controlled ionic strength cases, where the pH was also controlled at 11.5, there is little difference between the calculated plutonium solubility with $\log_{10} K_1 = 40.7$ or 9.9. Plutonium solubility under these conditions is mostly accounted for by the $Pu(OH)_5^-$ complex. The $PuCO_3^{+2}$ concentration is insignificant when $\log_{10} K_1 = 9.9$. For the group of experiments in which the ionic strength and pH varied, the plutonium solubility is also relatively independent of the magnitude of K_1 for high pH ($pH \geq 11.4$). At lower pH, the calculated plutonium solubilities using $\log_{10} K_1 = 9.9$ are more in line with the experimental solubilities. Thus, for most of the experimental conditions employed by MG, the choice between 40.7 and 9.9 for $\log_{10} K_1$ makes little difference in the calculated plutonium solubility. When there is a significant difference, $\log_{10} K_1 = 9.9$ gives better agreement between calculated solubility and the experimental results.

The solubility of uranium and plutonium in Well J-13 water was also recalculated with EQ3, using $\log_{10} K_1 = 9.9$ as the formation constant for $PuCO_3^{+2}$. The plutonium solubility was thereby reduced substantially. For the calculations where $\log_{10} K_1 = 40.7$, the primary aqueous plutonium species was $PuCO_3^{+2}$ in all cases. For the calculations where $\log_{10} K_1 = 9.9$, the primary aqueous plutonium species varies with Eh and pH, being PuO_2^+, $PuO_2CO_3^{2-}$, $Pu(OH)_5^-$, or Pu^{3+} under different conditions. The solubility of uranium in Well J-13 water is influenced by the choice of $\log_{10} K_1$. Under oxidizing conditions (Eh = 700 and 400 mV), when uranium(VI) is the primary oxidation state, aqueous complexes between UO_2^{2+} and CO_3^{2-} can form. For the calculations where $\log_{10} K_1 = 40.7$, all carbonate is tied up with plutonium so that little is available to complexes with uranium. For the calculations when $\log_{10} K_1 = 9.9$, the higher CO_3^{-2} concentration increases the concentration of uranium(VI)-carbonate complexes and thus increases the solubility of uranium. Under reducing conditions (Eh = -200 mV), uranium exists primarily as uranium(IV). No complexes of uranium(IV) with carbonate are available in the EQ3 data base (either they are not stable or thermodynamic data are unavailable), so the uranium solubility is unaffected by changes in $\log_{10} K_1$.

Conclusions--The objective of this analysis was to assess the effect of carbonate on the solubility of plutonium, particularly Pu(IV). It became obvious after some initial calculations that the stability of $PuCO_3^{+2}$ complex, as indicated by the work of MG, would dominate plutonium solubility whenever carbonate is present. However, the MG data have been criticized as indicating that $PuCO_3^{+2}$ is much too stable. The value for the formation constant based on their work ($\log_{10} K_1 = 40.7$) is not consistent with other actinide aqueous-complex data; a value of $\log_{10} K_1 \cong 10$ is more in line with other actinides.

The EQ3 computer program was used to calculate plutonium solubility under the conditions of the MG experiments. Although these calculations must be considered approximate because of the high ionic strengths involved, they indicate that one of the major assumptions used to analyze the MG data, that $PuCO_3^{+2}$ is the primary aqueous plutonium species under the experimental conditions, is not valid. Because of the high pH employed in these tests, $Pu(OH)_5^-$ is the primary aqueous species under most conditions. The plutonium-oxalate complex measurements made by MG were at very low pH (pH $\cong$ 1), where hydroxyl complexes would be insignificant.

The plutonium solubilities calculated by EQ3 using $\log_{10} K_1 = 9.9$ are in better agreement with the measured results than are the calculated solubilities using $\log_{10} K_1 = 40.7$. However, the agreement is far from good. There are a number of possible reasons for the differences.

a. Inaccurate activity coefficients caused by the high ionic strengths may contribute to disagreements. An examination of analytical results shows that plutonium solubilities are affected by the change in ionic strength from 7 to 10.

b. Inaccurate thermodynamic data for aqueous complexes in EQ3 may also lead to some disagreements. The EQ3 data base is probably the best available at this time, but inaccurate formation constants or missing data for some complexes are still possibilities. The formation constant for the complex $Pu(OH)_5^-$, which is important under these experimental conditions, is consistent with formation constants for other actinide hydroxyl complexes.

c. Uncertainties in the experimental conditions may also result in disagreements. The EQ3 calculations indicate that plutonium solubility is a strong function of pH under the conditions of the MG experiments. Also, solution Eh was not reported. Calculations were done at Eh = 400 mV; at higher Eh, Pu(VI) and its aqueous complexes become important, thus increasing the solubility of plutonium. Plutonium solubility was unaffected by decreasing the solution Eh below 400 mV.

The primary conclusion of this analysis is that the potential importance of Pu(IV)-carbonate complexes and the uncertainty in their thermodynamic data warrant an experimental investigation of this system. Carbonate is an important complexing agent in essentially all natural waters; thus, plutonium-carbonate complexes must be considered at all repository sites, not just at Yucca Mountain.

Plutonium Chemistry in Near-Neutral Solutions

Plutonium(IV) polymer is of environmental importance because it may provide a mechanism for transport, either directly or by adsorption onto fine particles that may be transported. Conversely, large polymer particles would be expected to be filtered out by the geologic media, and adsorption onto immobile phases would contribute to retardation. For these reasons, work is continuing on polymeric forms of plutonium.

In an earlier report, it was shown that when Pu(IV) in acid solution is diluted so as to give plutonium concentrations near 3×10^{-6} M and a pH of about 3, all the species capable of rapid reaction with Os(II) complexes disappear within one or two hours. It was concluded that most of the product of this reaction is Pu(IV) polymer because very little (about 10 percent) Pu(III) and/or Pu(V) was found using Ce(IV) as the reagent.

These experiments were repeated at higher concentrations to decrease analytical difficulties, and the results show that approximately half the initial Pu(IV) is converted to Pu(III) and Pu(V). A solution 1.2×10^{-5} M in total plutonium was prepared in 10^{-3} M acid, and aliquots were treated periodically with either Ce(IV) sulfate or $Os(dimebipy)_3^{2+}$. After three minutes, reaction with Os(II) showed that about 60 percent of the original Pu(IV) remained. After 330 minutes, essentially all the Pu(IV) had disappeared. After 340 minutes, reaction with Ce(IV) showed that about 45 percent of the original Pu(IV) had been converted to Pu(III) and/or Pu(V). This is consistent with approximately equal rates for disproportionation and for polymerization under the conditions of the experiment. The overall rate of disappearance of Pu(IV) observed is in agreement with the results reported in an earlier report. The effects of pH and plutonium concentration on the relative rates of disproportionation and polymerization have yet to be determined.

The precipitation and adsorption properties of diluted Pu(IV) prepared as described above may be important in the environment; therefore, they were investigated in preliminary experiments.

The Pu(IV) solution was diluted to 6.2×10^{-6} M in 0.001 M acid and pH was then adjusted to 5.1 by the addition of a 1-M pyridine solution. This base was used because it forms a buffer that is useful for pH values between 4.5 and 6, and it does not appear to complex plutonium in this range.

Centrifugation for four hours at 12,000 rpm (28,000) or filtration through 0.4-micrometer Nuclepore filter removed 57 ± 10 percent or 64 ± 7 percent of the plutonium, respectively. More plutonium was removed by filtering the supernatent from centrifugation through a 0.05-micrometer membrane; after this treatment, only 19 percent of the original remained dissolved or suspended.

Adsorption onto Pyrex was observed. This material was ground, sieved to give particles in the range from 106 to 150 micrometers, washed with hydrochloric acid, and thoroughly rinsed with water. Ratios of weight of solid to volume of solution ranged from 0.56 to 5.11 mg/ml. After three days of contact, about two-thirds of the plutonium in a 6×10^{-6} M solution at pH 5.1 was

absorbed onto the largest glass sample. The distribution ratio showed no trend with amount of glass and averaged 0.41 ml/mg with a mean deviation of 0.08 for four determinations.

This adsorption is irreversible in the sense that only about 2 percent of the plutonium was removed in 0.001 M acid and only 5 percent in 0.01 M acid.

Similar experiments, also at pH 5, using two forms of silica, 9-micrometer powder and diatomaceous earth, showed that about 60 percent of the plutonium was adsorbed in 30 minutes, independent of the amount or type of silica used. The ratios of solid to liquid were in the range from 0.6 to 2.9 mg/ml.

Further experiments will involve longer contact times, other solids, and attempts to characterize the nonadsorbed material with respect to filterability and the presence of reducing species [Pu(III) and Pu(IV)].

Precipitation and adsorption experiments were also done using green polymer prepared at a concentration of 8×10^{-3} M in approximately 0.04 M hydrochloric acid. Polymer prepared in this way is easily characterized by its optical absorption spectrum. A polymer suspenson was diluted to 6×10^{-7} M total plutonium at a pH of about 5; it was found that about 96 percent of the plutonium could be removed either by centrifugation for three hours at 12,000 rpm or by filtration through 0.4-micrometer Nuclepore membrane. This result indicates that the solubility of the polymer is less than 2.4×10^{-8} M. Rai and Swanson report a solubility of 5×10^{-7} M at pH 5; they do suggest, however, that most of their soluble material was in the form of Pu(V) rather than Pu(IV), although the oxidizing agent was not identified. They also report that solubility equilibrium was reached in about eight days. The apparent solubility of our polymer was found to increase slightly with time. After 45 days in contact with air, the concentration of plutonium that remained after centrifugation had doubled.

In another experiment, 3×10^{-6} M total plutonium was used at a pH of 4.5 and it was found that only about 13 percent of the plutonium could be removed by centrifugation at 12,000 rpm for 2.5 hours. This suggests a strong dependence of solubility on pH. Further experiments will be required before the apparent discrepancies between the results and those reported by Rai and Swanson will be understood.

The effect of HCO_3^- on the precipitation of polymer was observed in a single exploratory experiment. In 0.5 M NH_4HCO_3, only about 27 percent of the plutonium in a 6×10^{-6} M suspension was removed by centrifugation at 12,000 rpm for two hours. This is a larger "solubility" than might be expected and might be due to carbonate complexing or to the adsorption of carbon dioxide by the polymer.

Adsorption of the green polymer onto SiO_2 and ground Pyrex was briefly investigated at a pH of 4.6. The amount of plutonium adsorbed from 3×10^{-6} M solutions during a 1,000-minute contact period was found to be independent of the solid-to-liquid ratio in the range from 0.5 to 2.7 mg/ml. The amount of plutonium adsorbed was 94 percent for the SiO_2 and 83 percent for the Pyrex.

Further work at lower concentrations will be required before this adsorption behavior can be explained.

Particulate Transport

Most studies concerning the transport of radioactive material away from a repository have assumed that the waste form dissolves, then moves as ions in solution. An alternate mode of transport involves the radioactive material moving as a particulate suspension in the groundwater. Particles of colloidal size (about 1 to 10^{-3} micrometer in diameter) may remain suspended for very long periods of time and, hence, migrate at the rate of groundwater flow. The radioactive particles may form from leaching of the solid-waste form, from sorption of dissolved radionuclides on nonradioactive particles, or from the formation of colloids by radioactive species (for example, actinide hydrous oxides).

Various mechanisms may act to remove particulates from groundwater. Mechanical filtration will remove larger particles. Particles may sorb on the surface of rock pores, held there by van der Waals forces. The presence of ions in solution, particularly multivalent ions, may neutralize the electrostatic repulsive charges on the colloids, allowing them to coagulate.

Studies of particulate transport as it may occur in tuff derived from the NTS were initiated. Initial work has involved determining some limiting parameters that control the mechanical aspects of this phenomenon. For this purpose, commercially manufactured polystyrene beads and fluorescent resins not soluble in water were used. In later experiments, colloidal material more like that which may be encountered in a repository environment will be used.

A fluorescent resin was obtained from the Day-Glow Color Corporation, Cleveland, Ohio. This material was a mechanically ground powder with a wide range of particle sizes. Filtration of water suspensions through 0.4- and 0.05-micrometer Nuclepore membranes separated the smaller particles for subsequent use. Suspensions of these small particles (less than 0.05 micrometer in diameter) were stable over periods of several days, with no evident settling. Several qualitative experiments were performed with these Day-Glow suspensions. It was observed that the suspension readily passed through a crushed-rock column containing G1-1883 tuff rock fragments in the size range of 106 to 250 micrometers in diameter. Similarly, the suspension was drawn through an intact disc of G1-2840 tuff 0.70 mm thick. A fluorometer is on order and, when it arrives, the losses of the particulate resin during passage through crushed rock or solid rock will be quantified.

Polystyrene microspheres with nominal diameters of 3 and 9 micrometers were obtained from the 3M Company, St. Paul, Minnesota. Some of the 9-micrometer microspheres were labeled with ^{85}Sr. The nonlabeled microspheres were readily observable with an optical microscope. The 9-micrometer spheres were remarkably uniform in size, but the 3-micrometer spheres included an appreciable fraction of smaller spheres that appeared to range in size down to about 1 micrometer. It was found that some of the 9-micrometer microspheres

could be carried through the crushed-rock column by rinse water flowing under the force of gravity. Most of the spheres were retained by the column. Of these, many were not stopped by purely mechanical trapping because when the column was rinsed with ethyl alcohol, a large number of the spheres were eluted. Attempts to observe passage of the microspheres through the tuff disc were unsuccessful, including those down to 1 micrometer in size. Neither repeated water or alcohol rinses seemed to carry any spheres through the solid-rock matrix. Experiments are now under way to study particle transport along fractures in solid-rock cores.

Phase Change Studies

Experiments have been started that examine the phase changes in tuffs of varying mineral composition at known values of pressure and temperature. The samples are ground and enclosed in gold capsules with water present. The capsules are then placed in standard cold-seal pressure vessels that are pressurized and heated to the desired conditions. In these experiments, water pressure is equal to the total pressure. The mineral compositions of the starting materials and the compositions of final products after two weeks at 400°C and 400 bars and after four weeks at 300°C and 400 bars were determined.

The experiments are preliminary, but they do illustrate several interesting points. The upper stability limit of mordenite is apparently below 400°C at 400 bars in most of these rocks; however, in sample BH, a tuff from Buckhorn, New Mexico, mordenite is apparently stable at 400°C. Two explanations are possible. The mordenite may be metastable at 400°C; this seems unlikely because clinoptilolite in the other runs at 400°C did not produce mordenite. More likely, the stability of mordenite in this sample is due to a difference in composition. Such a difference might be in the ratio of potassium to sodium. There is also some indication that the mordenite in these samples is stable above 300°C. In those samples that originally contained clinoptilolite and mordenite, mordenite has crystallized at the expense of clinoptilolite. This is, however, not definitive evidence of mordenite stability. Mordenite may well be a metastable product of clinoptilolite decomposition. Certainly this is the case for cristobalite, which is known to be metastable with respect to quartz under these conditions. The observation of mordenite growth at the expense of clinoptilolite also indicates that the upper temperature stability limit of clinoptilolite is less than 300°C at 400 bars water pressure. Sample G2-547 indicates that this may also be true for montmorillonite.

Fifteen-week runs were completed at 200°C and 400 bars, but no change was observed in any of the samples. In samples G1-1319 and G2-547, where glass and feldspar are present, the lack of change is certainly due to the slowness of the kinetics. In the remainder of the samples, the mineral assemblages present may be stable under these conditions. Larger quantities of the materials are currently being run to produce material with which to reverse the reactions that have been observed.

Preliminary hydrothermal experiments have provided evidence on the upper thermal stabilities of clinoptilolite and mordenite at 400 bars water pressure. The upper stability of mordenite is probably between 300 and 400°C, and that for clinoptilolite appears to be below 300°C. These conclusions are made somewhat uncertain by lack of knowledge of the exact compositions of the minerals and by questions of metastability.

Future work will attempt to reverse the reactions that have been observed and determine the bulk compositions of the starting materials.

Microbiological Activity at Yucca Mountain

Routine microbial analyses have been performed on the drilling polymer and soap currently in use at Yucca Mountain. Initial results suggest that both substances can serve as growth substrates for microorganisms.

Soil samples were obtained at two drilling locations in Yucca Mountain. One location was receiving discharges of the polymer, and the other site was exposed to the soap. Two samples from each site were collected, placed in polypropylene bottles, stored at ambient temperature, and immediately returned to Los Alamos for analysis. Samples were collected from these areas because it was felt that such soils would be good sources of microorganisms capable of degrading soap and polymer.

Initial analysis consisted of transferring small amounts (1.0 gram) of soil onto a solid medium or into a liquid medium. Because both media contained no nutrient energy source other than the soap or the polymer, any growth in these media can be interpreted as a direct use of these materials by the growing microorganisms. Some nutrient carryover could occur; that is, small amounts of nutrients from the soil could be transferred along with the microorganisms. To avoid that, additional transfers of the growing microorganisms are usually made, thereby diluting out any nutrient carryover.

Preliminary results strongly suggest that both the soap and the polymer can serve as energy sources for soil microorganisms, because luxuriant growth occurred in all the media. Upon closer microscopic examination, all media contained mixed cultures of microorganisms, with many species being motile. Several colony shapes were present on the solid media, with many exhibiting significant mucoid excretions. These excretions are usually characteristic of known biodegraders, such as the pseudomonads. From the first set of solid nutrient media, several colonies were transferred to a second set of nutrient media. Here again vigorous growth occurred, and because no nutrient carryover could be present after the transfer, it is assumed that the microorganisms were using both the soap and the polymer as energy sources.

These results demonstrate that there is strong potential for microbial activity in drilling fluids; however, it should be stressed that the effects of such activity are, as yet, unknown. Because changes in soil pH and Eh are concomitant to a growing microbial population, one could postulate that radionuclide movement could be affected by microbial use of drilling fluids. In addition, many researchers strongly suspect that soil microorganisms provide chelating agents that also affect metal movement in soil systems.

Crushed-Rock Columns

All previously reported crushed-rock column experiments have been terminated and the results reported. A new set of crushed-rock column experiments has been initiated; these columns are being run at higher flow rates than those heretofore. The flow rates have been chosen to minimize diffusion spreading and to observe peak spreading that could be attributed to mass transfer kinetics. The peak shapes will be compared with chromatography theory and other sorption models. Aniomic tracers will be used with these columns to observe the anion exclusion effect produced by various mineral compositions.

The following crushed-rock columns have been prepared and correspond to whole-core columns that are being run concomittantly: G1-2698, G1-2233, G1-2234, G1-2840, G1-2410 (all 38- to 106-micrometer wet-sieved fractions), and G1-2854 (38- to 75-micrometer wet-sieved fractions). The densities and free-column volumes of these columns have been determined and the columns will now be spiked with $^{95}Tc^{m}$, ^{85}Sr, ^{137}Cs, and ^{133}Ba.

The sorption of TcO_4^- on the 106- to 150-micrometer fraction of crushed Climax Stock granite had been attributed to the possible presence of hematite. The experiment has now been repeated using Climax Stock granite crushed in an agate ball mill. The sorption of TcO_4^- has not been observed in the latest experiment, and the previous results are now attributed to iron contamination.

Solid-Core Columns

The following whole-core columns have been prepared and spiked with HTO: YM-54, G1-2854, G1-2289, G1-2840, G1-2334, and G1-2410. The dispersivities and kinetic void volumes will be determined. These columns will be spiked with $^{95}Tc^{m}$ to determine the effect of anion exclusion in solid-core columns. In addition, the columns will be spiked with ^{85}Sr, ^{137}Cs, and ^{133}Ba. Two columns of tuffs, G1-2840 and G1-2334, have been prepared for use with a high-pressure metering pump. These columns will be used to observe transport at high fluid velocities to detect the effect of mass-transfer kinetics.

Dependence of the Sorption Ratio on Element Concentration

It is important to determine the type of sorption isotherm for different elements on different tuff samples for diffusion and transport calculations.

Batch sorption measurements have been performed with a wet-sieved, 75- to 500-micrometer fraction of sample G1-2840, a devitrified tuff. Experiments performed with strontium and cesium have been completed. The results for strontium have been determined and the data for cesium experiments are being processed.

Twelve solutions of different strontium concentrations traced with ^{85}Sr were prepared with rock-treated water that had been filtered through 0.05-micrometer Nuclepore membranes. The strontium concentrations were measured with a plasma-emission spectrometer and ranged from 10^{-7} to 10^{-3} M. Duplicate experiments were performed for three weeks at ambient temperature under atmospheric conditions. For the cesium experiments, 12 traced solutions

of different concentrations were prepared by diluting a standard cesium solution and mixing with ^{137}Cs. Cesium concentrations ranged from 10^{-9} to 10^{-3} M.

Sorption ratios remain practically constant for initial strontium concentrations between 10^{-5} and 10^{-7} M and usually increase as the concentration decreases. The strontium concentrations in solution and on the solid after the contact time were determined for each sample. The isotherm obtained is not linear, but the data fit a Langmuir isotherm. This information will be useful for modeling purposes.

Determinations of Anion Concentrations of Groundwater

A mobile laboratory was set up with equipment for groundwater chemical analyses. Because the Dionex ion chromatograph, which was used extensively for analyses of anions, was part of the instrumentation to be moved to the NTS, an alternate means of running anion analysis using the Spectrophysics HPLC instrument at Los Alamos was investigated. Experiments were run using a Vydac analytical anion column with a Wescan conductivity detector and phthalic acid eluent, and with the Dionex analytical column (no suppressor) and benzoic acid eluent. It was not possible to use the suppressor column, normally used on the Dionex instrument, on the Spectrophysics instrument. Fluoride could not be analyzed on the Vydac column. The Dionex column showed more promise, but further studies to determine detection limits, et cetera, must be done to establish whether that method could be used routinely for anion determinations. Experience with the Dionex columns, using the suppressor installed on the Dionex instrument, seems to be much more satisfactory and straightforward.

Fe(II) Analyses

Analyses performed on several Yucca Mountain cores showed Fe(II) contents in the 1- to 100-ppm range, or less except for that in a core from the Tram unit in USW-G1 at 3,252 feet, which was in the few percent range. Trace pyrite was found at 3,371 feet in this unit, although none was found above this depth. Sulfide interferes in the procedure used to determine Fe(II). [The sulfide reacts with the ^{131}ICl to form $^{131}I_2$, which is the measurement for Fe(II).]

Natural Chemical Analogs

The study of geothermal sites in felsic tuffs like those at Yucca Mountain will give essential information on the long-term behavior of such tuffs in the near-field thermal gradient of a waste repository. A three-year program plan has been developed that includes (1) a literature search for published information on hot spring localities in Nevada and an initial selection of those that occur in felsic volcanic tuff, (2) acquisition of as much information on the localities as possible from published literature and from knowledgeable workers in the field, (3) our own investigation of the two or three most promising felsic tuff hot spring localities, and (4) a modeling effort integrated with other transport and reaction modeling to describe the chemical behavior of major and trace elements moving within a temperature gradient in felsic tuff.

The literature search was completed. After consideration of potential localities, a site near Beatty, Nevada, was chosen for the initial study. A field trip was made to the Bailey Hot Springs at Beatty, and the rocks of the area were examined and sampled. The hot springs emerge from felsic tuffs like those of Yucca Mountain and over a long period of time, the warm groundwater has strongly altered the felsic tuff. The samples will be analyzed for mineral phase assemblage alteration and to determine what materials have been removed by leaching by the warm groundwater and what materials have been added by precipitation from the water.

1.3.2.2.2 Mineralogy/Petrology

Objective: To determine the major mineral phases present in strata encountered in the drilling exploration program and to determine their relative abundances, textural relationships, chemical properties, and stability relations where appropriate.

Summary Studies

During this quarter, a summary of the mineralogy-petrology of Yucca Mountain tuffs was compiled. In this summary, the findings from studies on five drill holes are related to the problems of characterizing Yucca Mountain and determining critical aspects of mineral stability. Studies of mineral stability are still in progress; studies of natural zeolite and clay compositions are also incomplete, but some of the data now available for drill core USW-G2 are summarized here.

Zeolites (Clinoptilolite-Heulandite)--Compositional zonation in the heulandite-to-clinoptilolite series is common in the altered tuffs of Yucca Mountain, with compositions ranging from calcium- to potassium- to sodium-cation end members with increasing depth. Detailed zeolite compositions have been collected in part for drill hole USW-G1, and for a more complete suite on drill hole USW-G2. The data obtained represent our current knowledge of the heulandite-clinoptilolite zonation at Yucca Mountain.

The progressive transition from heulandite to potassium-clinoptilolite to sodium-clinoptilolite is evident. This is the expected pattern of variation with depth, but the details of composition suggest that content of the major large cations, calcium, potassium, and sodium, do not vary systematically with depth. For example, calcium content decreases as potassium content rises, but increases again with greater sodium content at depth. The general patterns of variation in these major large cations do not suggest any systematic depletion or enrichment with depth. The minor cations titanium and barium do not occur in concentrations significantly greater than microprobe detection limits. Content of iron is significant in some samples at 935 to 973 meters, but is greatly variable between samples at this depth. Content of magnesium is significant only in the sodium-poor samples from the upper part of the core; it is not known whether the anticorrelation between sodium and magnesium is determined by depth of zeolitization or by the compositions of rock and fluid at the time of zeolitization.

Previous studies in the vicinity of Yucca Mountain suggest that large amounts of cation exchange are required for the formation of heulandite-clinoptilolite zeolites from siliceous volcanic glass. Hoover suggests that the zeolite zoning took place after the formation of clinoptilolite and consisted of sodium replacement for calcium and magnesium; the high calcium and magnesium contents of the first-formed zeolites resulted from groundwater transport and concentration. Carr suggested that the calcium concentration was coupled with leaching of silicon, sodium, and potassium from primary glass. The occurrence of mordenite compositions intermediate between glass and clinoptilolite-heulandite zeolites led Carr to propose that the formation of mordenite may be a precursor to clinoptilolite-heulandite zeolitization. Many questions about the zeolite formation sequence and compositional zonation are still largely unanswered.

The thermal stability of sorptive zeolites is of potential importance to a high-level waste repository in tuff. Smyth summarized the available data on zeolite stability and suggested that adverse reactions (for example, reactions that liberate water and open fractures) can be avoided by keeping the zeolite-bearing horizons saturated and at temperatures below about 85°C. Appropriate long-run experiments, however, have not been established. Such experiments are critical for determining the variable effects of temperature, water pressure, and water composition. Stability over geologic time periods can be modeled from kinetic parameters obtained from experimentation. These models will be critical to projecting stability and retardation ability into the repository's isolation period. A final but very important factor in the model will be the composition of the zeolites, which is a crucial issue in retardation. It is known that short-term heating will readily degrade heulandite at temperatures as low as 250°C, but clinoptilolite will not immediately degrade until temperatures of about 700°C are reached. This suggests that a similar disparity in thermal stability might be found at lower temperatures maintained for longer time spans on the order of 10^2 to 10^4 years. These problems are presently under investigation.

Clay Minerals--Clay minerals are almost widespread throughout the tuffs of Yucca Mountain. Although abundances of clay are typically 5 to 15 percent, abundances as high as 50 percent occur in some units. Tuffs in the upper 150 meters of Yucca Mountain, which retain tridymite and cristobalite, also contain very little clay. There is, in addition, a general anticorrelation between abundances of clays and zeolites; the most zeolitized units such as the tuff of Calico Hills have the least clay. This relationship between zeolites and clays suggests that clay formation requires a permeable environment, and the decrease in permeability following zeolitization may inhibit clay formation. Textural evidence also suggests that clays form after zeolitization. Although some smectites occur as a late-stage fracture filling, most are concentrated in pumice relicts or scattered within the groundmass of these samples. The smectites in the upper portions of USW-G2 are predominantly sodium- and calcium-saturated montmorillonite-beidellites with few or no interstratified illite layers. The change from pure smectite to interstratified illite/smectite with depth is reflected both in X-ray diffraction studies and in the chemical composition of the clays. In general, the amounts of potassium and interstratified illite increase with depth, but

the smectites remain expandable until about 1,524 meters in USW-G2. Below that depth, nonexpandable illite and chlorite are present. In USW-G2, the transition from a one-water-layer smectite to a collapsed (but still expandable) smectite takes place at about 457 meters, but there are scattered occurrences of collapsed smectites above that depth and of several expanded smectites below 457 meters. At depths shallower than 1,067 meters, randomly interstratified smectite/illites occur, with a sporadic increase in the degree of interstratification with illite with depth. Below 1,067 meters there is an abrupt increase in the amount of interstratified illite, with ordered interstratifications appearing. Below 1,158 meters, a long-range, ordered, illite-rich interstratification occurs. The material is referred to as Kalkberg-ordered and occurs with illite abundances between 80 and 95 percent.

The randomly interstratified smectites/illites occurring shallower than 1,067 meters are consistent with temperatures of formation (less than 40°C). However, the ordered illites/smectites occurring below 1,067 meters suggest temperatures above 100°C, and the Kalkberg-ordered clays occurring below 1,158 meters are consistent with temperatures ranging from 180 to 230°C. Such an abrupt and, in places, sporadic increase in temperature cannot be explained simply through the imposition of a high paleogeotherm. These data, together with the occurrence of sulfides, barite, and fluorite in the lower parts of the drill holes, suggest that considerable hydrothermal alteration has taken place. There is some evidence for the presence of two generations of smectites throughout Yucca Mountain, and expandable smectites coexist with collapsed smectites in scattered samples down to about 1,524 meters and USW-G2. For example, the presence of a smectite with little or no interstratified illite at 1,508 meters in USW-G2, determined by X-ray diffraction, demonstrates that low-temperature alteration has taken place after the higher temperature hydrothermal alteration. This type of occurrence is evidence that hydrothermal alteration has not been pervasive for some time. Although hydrothermal alteration may be considered to be an unlikely future event, it might be advisable to date mineralized veins to determine the age of this hydrothermal system.

The stabilities of sodium and calcium smectites over geologic time spans are still poorly constrained. The effects of illite interstratification on smectite sorptive capabilities are also poorly known. What percentage of interstratified illite is allowable if high cation exchange capacities are to be retained? As with zeolites, the properties of smectites that are favorable for the HLW-repository isolation period are dependent on temperature, water pressure, and water composition. Experiments now in progress will take these variables into consideration.

Reexamination of Reported Erionite and Phillipsite Occurrences at Yucca Mountain

During this quarter, some reported occurrences of the zeolites erionite and phillipsite in drill hole J-13, and of erionite in drill hole UE25a-1H were reinvestigated. The reinvestigation, based on the same samples, showed no erionite or phillipsite in amounts above current detection limits by X-ray diffraction (about 3 percent) in either drill hole. The previous descriptions

were made either without the benefit of X-ray diffraction analysis or by much less precise X-ray diffraction methods than those currently in use.

Ongoing Drill Core Studies

Studies are in progress on drill cores USW-G3 and USW-GU3 and on bit cuttings and sidewall samples from hydrology holes USW-H3, USW-H4, and USW-H5. X-ray diffraction analysis for USW-G3/USW-GU3 confirms the petrologic observation that this drill hole is predominantly vitric from 1,195 feet to 1,598 feet in depth, with the first appearance of clinoptilolite as a major phase at 1,827 feet in depth.

Analcime first appears in significant amounts at 3,936 feet and is present to the bottom of the hole.

Petrographic studies of thin sections from 11 sidewall samples and bit cuttings from USW-H4 indicate that parts of the upper section (1,312 feet in depth) contain about 20 to 25 percent glass rimmed by cristobalite. However, the underlying samples are heavily zeolitized (1,420 to 1,550 feet in depth) or otherwise devitrified. Prepared specimens from hydrology holes USW-H3, USW-H4, and USW-H5 are now ready for electron microbeam and X-ray diffraction studies.

1.3.3 GEOLOGIC CHARACTERIZATION

Objective: To determine the geologic and hydrologic characteristics of candidate repository locations and to evaluate the feasibility of developing a mined repository.

1.3.3.1 Geologic Investigations

Objective: To locate and characterize rock masses on or near the NTS to determine their suitability for hosting a nuclear waste repository.

Drill hole USW-GU3 was completed to a depth of 836 meters overlapping with the adjacent drill hole USW-G3. Continuous core collected from GU3 within the unsaturated zone indicates that the tuffaceous beds of Calico Hills are vitric in the southern portion of Yucca Mountain ridge crest unlike the zeolitic alteration found farther to the north at USW-G1 and USW-G2.

Analyses of geologic data collected from USW-G3, USW-GU3, USW-H3, USW-H4, and USW-H5 and mapping of surface geologic features in the northern and western blocks of Yucca Mountain are in progress.

At the TIG/TPO meeting held in May at Menlo Park, R. B. Scott presented current fracture and fault information on Yucca Mountain.

As a member of the Ad Hoc TOC Committee, R. W. Spengler participated in several meetings which resulted in recommendations to TIG for shaft construction and potential Exploratory Shaft locations. Detailed surface geologic investigations were initiated at the potential Exploratory Shaft sites.

The drill hole report entitled "Stratigraphy, Structure, and Some Petrographic Features of Tertiary Rocks at the USW-G2 Drill Hole, Yucca Mountain, Nye County, Nevada," by Florian Maldonado and S. L. Koether, is currently being technically reviewed.

A paper entitled "Volcanic Stratigraphy at Yucca Mountain, Nevada, and Its Role in the Multiple Natural Barrier Concept of Waste Isolation," by R. W. Spengler, F. M. Byers, Jr., and Florian Maldonado, was presented at the Rocky Mountain Section meeting of the Geological Society of America on May 7-8, at Bozeman, Montana.

A paper entitled "Structure and Intracooling Unit Zonation in Welded Tuffs of the Unsaturated Zone, Yucca Mountain, Nevada; A Potential Nuclear Waste Repository," by R. B. Scott, R. W. Spengler, A. R. Lappin, M. P. Chornack, J. M. Brandt, and B. W. Cork, was presented at a Symposium on the Role of the Unsaturated Zone in Radioactive and Hazardous Waste Disposal at the American Geophysical Union Meeting held in Philadelphia.

R. W. Spengler presented current geologic investigations at the May NRC briefing.

1.3.3.2 Geophysical Investigations

Objective: To determine the subsurface distribution and configuration of geologic structures, rock units, and rock physical properties on or near the NTS.

Gravity

Gravity data are being obtained in the vicinity of the proposed drill hole (PH-1) near Busted Butte to aid in siting the hole.

The report, "Preliminary Results of Gravity Investigations at Yucca Mountain and Vicinity, Southern Nye County, Nevada," by D. B. Snyder and W. J. Carr was approved by the Director, USGS, and will be submitted to the printer in early July.

Magnetics

Quantitative interpretations do not support previous qualitative interpretations that a large intrusive rock mass similar to the Climax stock is present at shallow depth beneath Calico Hills. Recent studies indicate that most of the air and ground anomalies observed arise from strongly magnetized argillite, rather than intrusive rock. The gross configuration of the magnetic argillite is plate- like and extends 18 km westward into the Yucca Mountain area, and is present beneath the proposed site.

The remaining three of six planned ground magnetic profiles across Fortymile Wash were completed and five of the profiles have now been plotted. The data show numerous, short-wavelength anomalies of 25 nT to 250 nT in amplitude that, on cursory inspection, do not seem to be related to the Wash.

Because of the possibility of bias in the east-west flown drape aeromagnetic survey of Yucca Mountain, a similar magnetic survey is being contracted which will be flown in a north-south direction with a flight spacing of about one-half km.

Gordon Bath presented a paper at the Rocky Mountain Section of the GSA meeting at Bozeman, Montana, on "Relation of Aeromagnetic Anomalies to Faulted Volcanic Terrains at the NTS."

Seismic Reflection

Field data acquisition for the seismic reflection survey at Yucca Mountain will be finished in early July. Because previous surveys (by Colorado School of Mines in 1980 and Birdwell Division of Seismograph Services Corp. in 1981) failed to record usable data, a maximum effort was planned for this fiscal year. A field technique was tested along a line 3.2 km long using source and receiver arrays and a stacking procedure many times stronger than used in previous surveys. In spite of this effort, data quality remained poor. A preliminary stack showed possible reflections from depths of less than 457.2 meters but, in general, no usable data were obtained. From this information, it was concluded that attempting to record reflection data over Yucca Mountain using the planned arrays would not succeed. However, because of the possible shallow data, a field technique was designed which may record reflections from the shallow part of the section. Testing along 4.8 km of line in this mode is continuing.

Teleseismic Residual Studies

The P-delay experiment (fieldwork) in the Yucca Mountain region has been completed. In this experiment, 20 portable seismic stations were operated for about two months. The seismic array was centered on Yucca Mountain and occupied an approximately circular area of 15 km in radius. Together with the seismic stations from the permanent network operated by Al Rogers, the array had an average instrument spacing of 5 km. The teleseismic and regional earthquake data from the array will be analyzed to evolve a high-resolution P-wave velocity model of the crust in the Yucca Mountain region. The local earthquake data should provide accurate three-dimensional mapping of the seismicity of the region.

Petrophysics

Forty-four core samples obtained from Yucca Mountain drill holes UE25a-4, -5, -6, and -7 have been measured by L. A. Anderson for resistivity (d.c. and 100 hertz), induced polarization, grain density, and fractional porosity by both water and helium invasion methods, bulk density, acoustic velocity, hydraulic conductivity, remanent magnetization, and magnetic susceptibility. A report on the result of these measurements is being prepared.

Resistivity, bulk density, grain density, and fractional porosity for 97 core samples from the Yucca Mountain drill hole USW-G3 have been measured. Additional rock property measurements are also currently being made.

1.3.3.3 Hydrologic Investigations

Objective: To determine the present and past hydrologic regimes of the NTS and surrounding area as a basis for predicting future hydrologic regimes and the potential for hydrologic transport of nuclear wastes to the accessible environment.

Hydrology of Candidate Areas

Hydrologic wells USW-H4 and USW-H5 were drilled to depths of 1,219.2 meters. Hydraulic testing was completed in USW-H4 and was in progress in USW-H5 at the end of the quarter. Permeability in USW-H4 was broadly distributed below a depth of 563.9 meters, in the Prow Pass and Bullfrog Members and upper part of the Tram unit to a depth of 929.6 meters. Additional permeability was identified in the zone 1,179.6 to 1,191.8 meters. The water level in USW-H4 was similar to other nearby wells. However, in well USW-H5, the static water level is about 701 meters below land surface, or about 45.7 meters higher than the water level in the general area.

Work continues on report writing for well UE25b-1H; because of extensive gathering of field data at Yucca Mountain, only limited progress was made in data analyses for wells USW-H3 and USW-H4. The report for well USW-H1 received initial review.

Hydrologic Modeling

Further testing of the solute transport code was performed; results are positive, but more testing is required. Documentation of the code is in progress.

Copies of the code and data set used for the regional flow model were transmitted to the performance assessment group at SNL; these copies were forwarded by SNL to Pacific Northwest Laboratories (PNL) for their use. Technical discussions with SNL and PNL personnel on regional and Yucca Mountain hydrology were held on two occasions.

Analysis of data from UE29a-2 is under way. During the last two weeks of the quarter, pumping of a selected interval of UE25b-1H was begun in order to obtain high-quality samples of water for analysis by LANL. A bromide tracer was injected in UE25a-1 in an effort to obtain estimates of effective porosity.

Paleohydrology

A report, "Climates of the Last 45,000 Years at the Nevada Test Site and Vicinity," by W. G. Spaulding and F. L. Ugolini, was submitted to the USGS in fulfillment of a contract with the University of Washington. In the investigation, vegetative remains in rat middens were analyzed to reconstruct vegetative and climatic conditions during late Wisconsin and Holocene times. At the glacial maximum, temperatures were 6-7°C cooler and precipitation 30-40 percent greater than modern times.

An investigation to map Pliocene and Pleistocene rocks and geomorphic surfaces of the Ash Meadows Quadrangle, Amargosa Desert, is under way under the direction of Dr. R. L. Hay, University of California. Included in the study areas are widespread tufas and lake beds indicative of hydrologic conditions different from modern conditions. Determining the spring discharge and lacustrine history of the Amargosa Desert will contribute significantly to our understanding of the regional paleohydrology.

The following two reports were submitted for initial USGS review: "Flood Potential of Fortymile Wash and Southwestern Tributaries, Nevada Test Site, Southern Nevada," by R. R. Squires and R. L. Young; and "Sources and Mechanisms of Recharge for Groundwater in the West-Central Amargosa Desert, Nevada--A Geochemical Interpretation," by H. C. Claassen.

1.3.3.4 Tectonics, Seismicity, Volcanism

Objective: To assess the potential for faulting, damaging earthquakes, volcanic activity, and accelerated erosion to affect long-term repository performance.

Tectonics

Trenching of alluvium near faults has been completed on the east side of Yucca Mountain. Four sites on the west side of the crest remain to be trenched. Mapping of the trenches has been completed; no displacement of alluvium has been found.

Plans are being made for establishing a geodetic network in the Yucca Mountain area to monitor possible vertical and horizontal changes over a long period of time. Installation of a number of permanent benchmarks will be required.

A paper on paleoclimate of the Amargosa Basin by D. L. Hoover, R. L. Hay, and J. W. Hillhouse was presented at the Cordilleran Geological Society of America Meeting in Anaheim, California. The report outlined the climatic changes in the area during the past 3 Myr and concluded the general trend has been toward warmer and drier conditions.

A drill hole (PH-1), planned to reach subvolcanic rocks, was located on the east side of Yucca Mountain, about 3 km northwest of Well J-13. Pre-Tertiary rocks are expected within about 1,829 meters, but additional gravity work is being done to improve this estimate. This drill hole should provide geohydrologic information on the deep aquifers and structure at Yucca Mountain.

Seismicity

Two earthquakes of particular interest occurred in Death Valley on March 16; both occurred at the same location in the Salt Creek Hills and were about magnitude M_L 3.5. The location is about 4 km west of the Furnace Creek fault, about 20 km northwest of Furnace Creek Ranch, and about 50 km southwest of Yucca Mountain. Indicated mechanisms were right-lateral strike-slip on a fault that trends about N 15°-30° W. According to USGS Professional Paper

494-A by C. B. Hunt and D. R. Mabey (1966), the Salt Creek Hills are an area of youthful deformation where Quaternary gravels are folded and tilted. These moderate-sized earthquakes are typical of activity seen thus far in tectonically youthful Death Valley, where seismic activity is occurring, not on the major Death Valley-Furnace Creek system, but on subsidiary faults. Two-hundred thirty (southern Great Basin) micro-earthquakes were located and catalogued during the period January 1 through March 31, 1982. There were 26 having $M_L < 2.0$, 150 having 2 $M_L < 3.0$, and 54 having 3 $M_L < 4.0$. No earthquakes with $M_L > 4.0$ occurred, and there were no earthquakes at the Yucca Mountain site. Important areas of activity were Sarcobatus Flat, an area between Eureka Valley, Fish Lake Valley and Deep Spring Valley, northern extreme of the Last Chance Range, and Death Valley 20-25 km north-northwest of Furnace Creek Ranch. Pahute Mesa earthquakes are aftershocks of a nuclear event.

The hypocentral data in this quarterly report are based on revised velocity models for crustal P- and S-waves in the southern Great Basin. After reexamination of the literature, analysis of several velocity models, and discussions with L. C. Pakiser, the following essentially two-layer crustal model was adopted:

Depth to Top of Layer (km)	Vp (km/sec)
0.0	3.8
1.0	5.9
3.0	6.15
24.0	6.9
32.0	7.8

The 3.8 km/sec velocity is based on rock core velocities taken from drill holes at the Nevada Test Site (R. D. Carroll, personal communication, 1973). The lower crustal layer, beginning at a depth of 24.0 km, is based on Pakiser's interpretation of strong arrivals from chemical detonations as shown in the paper by Roller and Healy (1963). The reflection from this horizon is generally obscured by the use of data from nuclear explosions due to the very high energy levels in the early parts of the signals recorded. This result led to past speculation that, unlike the northern Great Basin which has a two-layered crust, the southern Great Basin consisted of a homogeneous single layer of relatively low P-wave velocity. Our predominantly two-layer crust for the southern Basin and Range is compatible with accepted data on the northern Basin and Range and gives the crust in the entire Great Basin province structural coherence.

This P-wave velocity model was used as the starting model for a simultaneous inversion for earthquake hypocenters, crustal velocities, and individual station terms, carried out with VELEST2 (Ellsworth and Roecker, written communication, 1980). For our final inversion, 50 of our best recorded and geographically widely distributed earthquake sources were used to determine average P-wave time corrections for each of our 59 seismograph stations. This final inversion was performed after considerable experimentation using nuclear shot arrival times from Yucca Valley and Pahute Mesa detonations to constrain

the results of the inversion. Because the constrained inversions (nuclear event cases) consistently produced an average station term for the entire network of about -0.42 seconds, it was concluded that these constraints were inducing an anomalous bias into the inversion. Thus, the inversion was performed treating all earthquake locations, layer velocities, and station terms as free variables whose solution was sought, and constraining the inversion with a Yucca Flat nuclear event with fixed location and free origin time. This inversion perturbed our starting velocity model by amounts less than 0.05 km/sec and, thus, left the starting velocity model unchanged. The resulting set of station terms were then independently confirmed using a fast joint hypocenter determination (JHD) algorithm (Herrmann, 1981) which simultaneously solves for hypocenters and station terms, given a velocity model.

Having a reliable average P-wave velocity for source-station terms, the corresponding S-wave velocity and S-wave station terms were determined. This was accomplished using the Wadati approach (Kisslinger and Engdahl, 1973) with six earthquakes which had well-recorded P- and S-waves. This resulted in Vp/Vs = 1.71 with the fits having a very low standard error. The low scatter of these solutions and their agreement for varying source-station paths is good support for our assumption that Poisson's ratio does not vary significantly throughout the crust of the southern Basin and Range.

Volcanism Studies

An open-file report by W. J. Carr, USGS, on drill hole USW-VH1 in Crater Flat was released to distribution during the quarter. No new volcanic units were found by this drill hole; however, it provided important evidence on the structure and possible Miocene caldera locations just west of Yucca Mountain.

A draft was finished of a major report on the stratigraphy, petrography, and volcano-tectonic relationships of the Crater Flat Tuff and subjacent units. These tuffs are the principal candidates for saturated zone storage at Yucca Mountain.

Crater Flat Volcanism and Possibilities for Magmatic Disruption at Yucca Mountain--A paper by Vaniman et al., which was submitted to the journal Contributions to Mineralogy and Petrology, summarizes the current status of volcanism studies at Crater Flat, Nevada. Hawaiite-type lavas were erupted in three cycles (3.7, 1.2, and 0.3 Myr) at Crater Flat. The compositions of all three cycles, considered together, form a "straddling" alkalic series as defined by Miyashiro, in which the less evolved basalts plot near the normative olivine- diopside divide and the more evolved basalts project into the hypersthene or nepheline fields. Fractionation modeling based on the oldest cycle allows the removal of olivine, clinopyroxene, and amphibole to arrive at the more evolved hawaiite compositions. In general, fractionation of phlogopite or feldspar is limited by the fractionation modeling and by europium-rare-earth element relations. In detail, all hawaiites within one cycle (3.7 Myr) cannot be derived from a single parent magma. Varied parentage is evident between cycles as well, although all cycles are consistently of hawaiite composition. Basalts of the youngest two cycles are generally enriched in trace elements. Superimposed on this enrichment is a

lack of rubidium variation, leading to rubidium/strontium ratios far lower than those required to generate the high $^{87}Sr/^{86}Sr$ ratio (0.707) typical of basalts in this region. The very low rubidium/strontium ratios limit processes that may lead to trace-element enrichment during magma evolution (cyclic recharge of a fractionating magma chamber). Decreased fractions of mantle melting, leaving phlogopite in the residuum, or an earlier event of metasomatic transport from phlogopite-bearing mantle rocks into a phlogopite-absent mantle assemblage might explain the observed trace-element enrichment with low rubidium/strontium.

A paper by Crowe et al., which was submitted to the Journal of Geology, treats the aspects of possible magmatic disruption of a high-level waste repository in southern Nevada. The NTS region is located in the central section of a north-northeast trending basaltic volcanic belt of late Cenozoic age, a part of the Quaternary volcanic province of the Great Basin. Future volcanism within the belt represents a potential hazard to storage of high-level radioactive waste within a buried repository located in southern Nevada. The hazards of future volcanism in the region are being characterized through a combination of volcanic hazards studies, probability determinations, and consequence analyses. Basaltic activity within the NTS region is divided into two age groups consisting of relatively large-volume silicic cycle basalts (8 to 10 Myr) and rift basalts (less than 8 to 0.3 Myr). The rift basalts occur as small-volume (less than 0.1-km^3), spatially separate basaltic centers. The lavas are classified as hawaiites and show strong affinities to the alkalic basalt suite. They were derived from the upper mantle below a depth of 30 to 35 km and were modified from parental compositions by crystal fractionation. Younger rift basalts (less than 4 Myr) are enriched in incompatible trace elements. Theoretical and geological considerations of basalt rise rates indicate rapid ascent of basalt (tens of cm/s) within the bubble-free regime. Rising basalt magma is probably trapped at the crust/mantle density interface. The magma probably crystallizes high-density phases (olivine, pyroxene) that decrease the liquid density due to crystal removal. As the density decreases, the magma reinitiates rapid ascent through the crust. Field studies and geometrical arguments suggest that basalt centers are fed at depth by narrow, linear dikes (aspect ratio 10^{-2} to 10^{-3}). However, in some cases, shallow intrusions are formed (Paiute Ridge and Nye Canyon area of the NTS). These intrusions probably formed through a combination of factors during emplacement, including extension faulting and trapping by low-density tuff as a result of low magma-volatile content. Surface basalts comprise single or coalesced scoria cones of moderate size with associated lava flows. Eruptions were predominantly of Strombolian type. The rise rate of basaltic magma for these centers was probably in the low range of typical basalt rise rates based on ratios of cone volume to lava volume and short lava lengths. Potential dispersal pathways of radioactive waste incorporated and dispersed through Strombolian eruptions are traced, assuming magma intersects a repository at depth. It is assumed that waste elements are incorporated and transported in basalt magma in a manner similar to that of lithic fragments. Such fragments are probably engulfed during magma disruption and fragmentation and are partitioned preferentially in the pyroclastic component of an eruption. Assuming a future magmatic cycle of volume similar to that of the Lathrop Wells cone of the NTS region, 54 m^3 of material from a repository horizon will

be deposited in a scoria cone (of which 2.7 m^3 will be exposed at the surface in a 10,000-year period), 96 to 245 m^3 will be incorporated in a scoria sheet (2- to 12-km dispersal), and 6.1 m^3 will be dispersed regionally with the fine-grained particle fraction (greater than 12-km dispersal).

1.3.3.5 Geochronology

Objective: To provide potassium-argon, fission-track, uranium-trend, and uranium-series ages on geologic samples for use in determining the history of geologic events and conditions in the NTS area.

Uranium-Series Dating and Stable Isotopes

Results of the stable isotopic composition of vug calcite from the Nevada Test Site cores are as follows:

Depth (feet)	^{18}O (permil)	^{13}C (permil)
113.0*	20.00	-4.52
919.1**	19.21	-8.35
927.5*	17.60	-6.33
991.8**	19.31	-7.90
1,137.6**	18.22	-7.43
1,137.8**	18.30	-7.37
1,144.0**	18.19	-7.47
1,144.4**	18.13	-6.93
1,177.8**	17.98	-6.82
1,183.0**	17.77	-6.56
2,004.0*	15.60	-5.41

*From drill hole UE25a-1.

**From drill hole USW-G2.

Reproducibility is very good as evidenced by the results from samples 1,137.6 and 1,137.8. Vent-filling travertine collected from the Amargosa Desert yield $\delta^{18}O$ values of +13 to +15 and $\delta^{13}C$ values of -1 to -2.

Fractionation of oxygen isotopes between calcite and H_2O at 20°C is about 29.5, so that the water in equilibrium with the shallowest NTS calcites would have a $\delta^{18}O$ value near -10. This value is typical of that meteoric water previously measured in this area and similar to the values of secondary carbonates measured in a variety of lavas and ultramafic xenoliths. These results indicate that the source for the oxygen in the NTS calcites is meteoric water.

The source for the carbon in the Amargosa Desert samples is dissolved atmospheric CO_2 and Precambrian carbonate as reflected by the near-zero values of the carbon isotopic composition. There are two possible sources for the carbon of the Test Site calcites. One source is dissolved atmospheric CO_2 in the groundwater which would result in carbonates with $\delta^{13}C$ values near -1 (t = 20°C). The other source is reduced carbon from either organic matter or from tuffs themselves; the $\delta^{13}C$ value of this source may approach -20. It is likely that most (e.g., greater than 70 percent) of the carbon comes from dissolved atmospheric CO_2 with a small contribution (e.g., less than 30 percent) from reduced carbon.

The decrease in $\delta^{18}O$ and increase in $\delta^{13}C$ with depth of the calcites probably results from an increase in the temperature of the meteoric water as it descends through the volcanic pile. $\delta^{18}O$ values of the carbonates indicate equilibration temperatures with water having a value of -10 or 17°C near the surface and 39°C for the sample at a depth of 2,004 feet. The corresponding enrichment of $\delta^{13}C$ by 2 permil of the calcites with increasing depth can also be explained by increasing the precipitation of the calcite from 17 to 39°C. These estimates correspond to a maximum geothermal gradient of 35°/km. This value represents an upper limit because the meteoric water and dissolved CO_2 can become $\delta^{18}O$-depleted and $\delta^{13}C$-enriched as a result of the precipitation of the carbonate.

The analytical results and calculated ages for cavity and fracture-filling calcite in core of drill hole USW-G2 at Yucca Mountain were obtained.

Calcites at 919.1- and 1,144.0-foot depths were coarsely crystallized cavity fillings. The sample at 919.1-foot depth yielded a uranium-series age of greater than 400,000 years Before Present (B.P.) and the calcite sample at 1,144.0 feet in depth yielded an age of 142,000 $\pm$ 20,000 years B.P.

The calcite at the 1,137.6-foot depth was fine-grained, lining the rock surface. It was not possible to separate the thin calcite lining from the rock completely. The sample was leached with 6M HCl solution, then both the acid-soluble and acid-insoluble fractions were analyzed. The age of the calcite deposition was calculated by means of isochrone plots of the isotopic ratios of the acid-soluble and acid-insoluble residue pair. The resulting isochrone-plot age is 189,000 $\pm$ 30,000 years B.P.

The approximately 1-cm-thick deposition at about 1,177.8-foot depth in a fracture zone was an admixture of uraniferous opal and calcite. The sample was separated from the bedrock and was ground to a fine powder. The calcite was separated from the opal by acid leaching. The two aliquots of calcite yielded ages of 170,000 $\pm$ 18,000 and 185,000 $\pm$ 18,000 years B.P., respectively.

The opal component at this depth has been analyzed separately. The uranium concentration of the opal is 27.0 ppm and its apparent age is greater than 400,000 years B.P. It was suggested recently that opal itself, under special circumstances, can be dated by the uranium-series method also. However, the ages obtained on the calcite aliquots and the age on the opal are in disagreement. The reason for this discrepancy and the general validity of using

authigenic opal as a reliable dating material in drill hole USW-G2 will be further investigated.

1.3.3.6 Drilling Plans and Engineering

Objective: To provide Project participants with technical support from the NTS contractors.

These support requirements are reported in the various task activity sections to which they are applicable.

1.3.3.7 Field Geology and Core Library Support

Objective: To provide and maintain a cadre of Fenix & Scisson geologists to support the Project participants, to provide and maintain core library facilities at the NTS for handling and storing rock samples, and to provide general NNWSI Project support to the USGS.

Fenix & Scisson geologists provided support to: (1) Subtask 1.3.3.1, for fracture studies of outcrops and core from USW-G3 and USW-GU3, monitoring of USW-GU3, and pumice flattening ratio; (2) Subtask 1.3.3.3, for monitoring and hydrologic testing of USW-H4, USW-H5, and UE25b-1H, and contribution to UE25b-1H report; and (3) Subtask 1.3.3.4, for continued field mapping of Quaternary deposits.

1.3.3.8 Weapons Test Seismic Investigations

Objective: To measure weapons-test-induced ground motion for determining its changes with distance, depth, and yield and to obtain site-specific ground motion data for evaluating potential repository sites.

Early in the quarter, a specially designed canister with a 3 1/8-inch diameter was installed at 1,850 feet in USW-G1. The canister was attached to a motor-driven hole jack to lock the unit in place. Amplification of the signals is done partly downhole and partly at the surface. Five amplifications of each of the three orthogonal accelerometer outputs permit band edge settings of 0.03, 0.3, 3, 30, and 300 milligs. Any two adjacent amplifications can be recorded simultaneously. Recent installation of six solar photovoltaic panels apparently will permit the station to be operated continuously for about a week before batteries need to be recharged. This continuous recording at the surface and downhole will monitor earthquake activity, and will provide surface-to-depth effects of earthquake motion for comparison with surface-to-depth effects from weapons test ground motion. A recent modification of the surface canister permits the same amplifications as for the downhole canister.

A total of 78 measurements, of which 18 were downhole, were made on the GIBNE event. A total of 81 measurements, of which 18 were downhole, were made on the NEBBIOLO event. In addition, three surface and three downhole measurements were made at USW-G1 on another event. Similar measurements at USW-G1 will be made during the next few months on events with yields smaller than those for which all stations are usually operated. This is to test the

functioning of the station at the high sensitivities, and to provide data to assist in deducing the orientation of the downhole canister.

Data analysis efforts have continued on the effects of depth using the Yucca Flat data set. The analysis of single- and multiple-peak data has been completed. Data for "vector" pseudorelative response velocity (PSRV) ratios have been prepared and plots made. Analysis of those data was ongoing at the end of the quarter. Preparation of plots of acceleration, velocity, and displacement for comparison of surface and downhole waveforms was about half completed at the end of the quarter. Several algorithms of transfer functions used to predict motion at depth from measured motion at the surface have been evaluated in an effort to find an optimum one.

The extent of the data processing effort which precedes and is a part of the data analysis is not very visible. The following is intended to convey some appreciation of what is involved in using the Yucca Flat data set in the effects of depth study.

-- Approximately 5.8×10^8 data points are involved.

-- If this were all processed at once, it would use 30 percent of the available disc storage on the CDC 7600 computer.

-- This data would require 10 nine-track digital tapes at a storage rate of 6,250 bits/inch.

-- About 20,000 data plots have been made and used for analysis, only a portion of which are visible in the reports.

-- A total of nine surface/downhole station pairs are involved.

-- Data from a total of 28 nuclear weapons tests are used.

1.3.4 HYDROLOGIC CHARACTERIZATION

(These task activities are included in Task 1.3.3.)

1.3.5 ENVIRONMENTAL CHARACTERIZATION

Objective: To perform the area-to-location screening and to inventory and analyze existing environmental information relevant to potential repository locations within the screening area.

1.3.5.1 Area-to-Location Screening

Objective: To develop the approach and to perform the area-to-location screening of potential repository rock units.

The final screening report, "Summary and Conclusions of the NNWSI Area-to-Location Screening Activity," SAND 82-0650, was revised and sent to the Site Evaluation Steering Committee for review and approval. Comments on an earlier

draft were received from LLNL and the USGS through their respective Site Evaluation Working Group representatives. Other comments were received from SNL technical staff, W. S. Twenhofel and B. L. Hartway, the latter two acting as consultants to the TOC. The revisd draft sent to the Steering Committee reflected these comments. A Steering Committee meeting was held May 14 to discuss the report.

The report ranks 15 alternative locations and 9 host rocks for both saturated and unsaturated conditions based on evaluations of how well various performance objectives are satisfied by 31 physical attributes. Northern Yucca Mountain (generally north of BLM land), northeastern Jackass Flats, and the area encompassed by Calico Hills-Upper Topopah Wash rate in order as the three best locations in the screening area. Argillite, granite, unsaturated Topopah Spring Tuff, and Calico Hills Tuff are the most highly rated rock types.

Problems encountered in transferring word processing discs of the text have caused delay in incorporating comments from the Site Evaluation Steering Committee in the final version.

Review and revision of supporting documents on the objectives and attributes used in the screening are continuing.

1.3.5.2 Environmental Area Characterization

Objective: To prepare an Environmental Area Characterization Report (EACR) that will be the initial data base for subsequent environmental impact analyses and to identify environmental factors and information significant for area-to-location screening.

Development of task statements with DRI/ASC for meteorological data processing and analysis was begun. The first of two 10-meter meteorological tower systems was installed near the east base of Yucca Mountain. Magnetic tape cassette recording began June 30. Eight measurements are taken at two-second intervals and averaged over 20-minute periods. The second system will be installed on the ridge in October.

TOC representatives for environmental issues participated in the Ad Hoc Working Group for recommending the Exploratory Shaft site and construction method.

A draft of the EACR was technically reviewed and revised. It has been submitted to WMPO/NV for policy review prior to returning it to Mitre Corp. for finalization.

Off-site and on-site background radiation reports were completed by REECo and EPA. Negotiations for revision of the water resources overview report were held with DRI/WRC. A contract was initiated to finalize the Energy and Mineral Resources Overview Report. Planning for the radiological monitoring program was also begun.

Significant archaeologial sites on Yucca Mountain and vicinity were toured with the principal investigator for archaeology and a geoarchaeologist. The DRI contract was modified to include work required for archaeological description. Twenty-nine significant archaeological sites will be tested to determine their potential to yield buried cultural remains containing information important to Yucca Mountain prehistory.

Additional funds were requested and approved for EG&G to complete Phase II of the Yucca Mountain biota survey. Vegetation association mapping of the study area has been completed. Detailed analysis of the species composition and relative densities of the major vegetative associations has been initiated. Transect surveys for vertabrate species have been completed. Seven trapping locations have been selected and small mammal live trapping has been initiated. EG&G was contacted to initiate a plan for mitigation of impacts on sensitive species and to determine the needs for mitigation during seismic and other ongoing exploration activities.

1.3.5.3 Horizon Selection Activity

Objective: To review and organize the technical information for evaluating, ranking, and selecting an at-depth horizon for further exploratory investigation.

The NNWSI is scheduled to complete the unit selection activity by the end of CY 1982. The result of unit selection will be a ranking of the four units at Yucca Mountain (Topopah Spring, Calico Hills, Bullfrog, and Tram) as to their suitability for a repository location. Two elements of the unit selection activity are hydrologic characterization of groundwater travel and thermomechanical analysis of rock response.

Very preliminary hydrologic calculations have been completed by Battelle-Pacific Northwest Laboratories (PNL) using properties measured in USW-G1 for units below the water table. Estimated hydraulic properties were used for the unsaturated zone. Simplified groundwater travel-time calculations were made assuming that flow in the unsaturated zone is vertically downward to the water table, and flow in the saturated zone is horizontal. The "accessible environment" in this case was assumed to be Well J-12. Results indicate that groundwater travel times in the unsaturated units to an existing well approximately 10 km distant are much longer than in the units below the water table. These calculations are particularly vague because of limited hydrologic data in the saturated horizons and limited understanding of water movement in deep, unsaturated rock.

The thermomechanical evaluation consists of three phases defined in the January-March 1982 quarterly report. In the Phase I calculations, rock-property average and limit values are used for unit ranking. The average and limit cases for the near-field (room and pillar) thermomechanical evaluation of each of the four units have been defined. Preliminary calculations (50 kW/acre, spent fuel, 1.6 kW/can), to determine the near-field (room and pillar) thermomechanical response of individual units based on average properties were completed for three of the four units under consideration. Calculations for the Topopah Spring Member have not been carried out yet. These

calculations were intended to provide examples of "expected" near-field responses, to help evaluate the concept of "factor of safety" as a performance constraint, and to provide input for the statistical unit evaluation. Results indicate no major problems will be encountered in the three units evaluated. Each rock type showed minor fracturing at the corners of the drifts. Thermally induced matrix fracturing around the waste canister was observed in the bedded tuffs, but was not enough to cause concern. However, the extent of fracturing depends on thermal expansion of the matrix and could be a problem for rocks that show more contraction upon dehydration than those considered.

Phase I near-field calculations being performed at Sandia National Laboratories were expected to be completed by the end of April. However, the schedule has been set back due to problems encountered in moving the thermomechanical codes ADINAT and SANDIA-ADINA from the CDC-7600 computer (which is no longer available at SNL-Albuquerque) to the CRAY-1. At this time, the codes appear to be running properly on the CRAY-1.

The average value cases for the far-field thermomechanical calculations have been defined. The thermomechanical functional stratigraphy has been translated to a spatial plot in Yucca Mountain, Cross Section C-C^{1}. The cross section, which defines a finite element mesh, has been forwarded to RE/SPEC which will use it in performing the far-field calculations.

The Unit Selection Activity also consists of near- and far-field sensitivity analyses (Phases II and III). A near-field sensitivity analysis for the Tuffaceous Beds unit has been defined.

Data Base Management System

The thermomechanical cross section, C-C^{1}, to be used in the Unit Selection calculations was completed on the Applicon. This cross section is based on mapped faults and thermomechanical data from drill holes USW-G1, UE25a-1, and UE25b-1.

Thermal conductivities, compressive strengths, tensile strengths, formal geologic stratigraphies, and the unpublished sorption stratigraphy were added to the data base file, TUFFDB. This data in the System 2000 will be accessible to the project after it is checked and safeguarded. Also included in the data base are several types of related information such as hole number and depth from which samples were obtained, sample history, testing methods, testing conditions, data sources (published and unpublished references), and a glossary.

Most of the above data in TUFFDB had been transcribed previously from published reports, typed on cards or discs, and entered in the computer. During this quarter, abbreviated formal geologic stratigraphies from UE25a-1 and USW-G1 went through a similar process. Sorption data (the sorption stratigraphy, as well as compiles sorption/desorption values from individual tests) were also put on the computer this quarter.

1.3.6 SOCIOECONOMIC EVALUATION

(No NNWSI work funded this fiscal year.)

1.3.7 SITE PERFORMANCE EVALUATION

Objective: To determine if new site performance evaluation techniques and/or more detailed data must be developed, particularly for basaltic volcanism, and to perform sensitivity evaluations in support of site characterization and performance evaluation.

The focus of the Systems Sensitivity Studies for Site Performance Evaluation has been on the horizontal emplacement of nuclear waste (as opposed to vertical emplacement). The emplacement of nuclear waste in long horizontal boreholes has several advantages, including a much lower extraction ratio than the floor emplacement concept. Horizontal emplacement also provides options for preserving some stand-off distance between the emplaced canisters and the walls of the drifts used by personnel. A preliminary thermal evaluation of this concept has been completed. The effect of stand-off distance on the access drift temperature was the major area of investigation. Calculations were made for a 1.6-kW spent fuel canister emplaced in either a welded, devitrified tuff or a nonwelded, zeolitic tuff. The maximum temperature at the access drift wall was determined for the first 100 years versus the temperature at stand-off distance for both rock types. For comparison, the floor temperature of a storage drift containing canisters emplaced 4 meters below the floor is also plotted. This indicates temperatures will rise substantially less if modest stand-off distances are used. For example, a stand-off distance of 0 meter yields a maximum temperature rise (assuming 35°C ambient) of 130°C to 190°C, while a 25-meter stand-off distance yields a maximum temperature rise of about 30°C, with less than 3°C for the first ten years after emplacement. The effect of decreasing the stand-off distance by adding canisters later (e.g., at the time of backfilling) was also investigated, and a method for determining its effect was developed.

A review of a memo on the thermal properties of canisters emplaced in horizontal boreholes has suggested further analyses of the effects of waste type, canister loading, and stand-off distance. A rough draft report of results from these analyses should be completed within the next quarter.

1.4 REPOSITORY

Objective: To establish the technological basis for repository development necessary to assure adequate repository and waste package containment and isolation capabilities.

1.4.1 REPOSITORY BASELINE

(No NNWSI work funded this fiscal year.)

1.4.2 REPOSITORY DATA BASE DEVELOPMENT

Objective: To develop the information needed to support the development of an adequate repository design.

1.4.2.1 Tuff Investigations

1.4.2.1.1 Laboratory and Modeling

Objective: To investigate several long-term effects of repository conditions on tuff.

Rock Physics Studies

This quarter the first creep test at elevated temperature and pressure was performed. Although the test was not completely successful because of a jacket leak, some interesting results were obtained.

The test specimen was a tuff from the Bullfrog Member at the 2,483-foot level of hole USW-G1. The sample was 11.1 cm long and 5.4 cm in diameter. The test conditions were 100°C, 50 MPa differential stress, 20 MPa confining pressure, and 5 MPa water pore pressure. The effective confining pressure of 15 MPa was attained initially, but due to a slow jacket leak that developed early in the test, the effective pressure slowly dropped over the duration of the test to about 50 percent of the initial value. Because of the slow decrease in effective pressure, axial strain actually decreased slowly from the initial loading value while circumferential strain increased slowly. Over the last 20 hours of the test, the average circumferential strain rate was about 1.2×10^{-9}/second; which increased very slightly in the last 2 hours. In retrospect, this almost imperceptible increase in strain rate reflected the onset of a type of tertiary creep that only developed strongly in the last 200 seconds of the test. Strain accelerated rapidly during this period, and the sample failed at a total test time of about 69 hours.

This type of sudden tertiary creep failure is similar to that observed in uniaxial, room temperature creep of Grouse Canyon welded tuff. In each case there has been little indication of the nearness to failure and, so far, no evidence of the classical exponentially increasing tertiary creep that has been observed in granite and other materials. This may be a reflection of the textured inhomogeneity of welded tuff samples. Failure may initiate in a very

local region with no general increase in microfracturing activity that might be noticeable at strain gauges outside of the ultimate failure zone.

Although this test alone does not establish a new issue of concern, it does suggest a type of potential failure that should be evaluated. In the near field of a repository in a material of very low permeability and relatively high water content, such as zeolitized tuff, thermal expansion of pore water or mineral dehydration water could lead to a local increase in pore pressure if the water could not leak off rapidly enough. The increase could lead to local rock failure initiation because of the reduction in effective pressure. This would occur while at least some of the strain monitors were indicating a decreasing rate of strain due to the decompression associated with a falling effective pressure.

1.4.2.1.2 Rock Mechanics Field Experiments in Tuff

Objective: To develop and implement test plans for determining and evaluating the in situ physical, chemical, and mechanical properties of welded tuff under simulated repository conditions.

The rock mechanics task is divided into the following activities:

NTS Facilities Preparation

The following activities have been accomplished in the G-Tunnel Underground Facility (G-TUF):

Drift Mining--Mining was resumed on the Extensometer Drift; the required mining was discussed and defined in the last quarterly report.

Experiment Drilling--Seven EX vertical exploratory holes were completed in the floor of the Experiment Drift for the Unit Cell Experiment. Six of the holes were 6.1 meters deep; the seventh extends to a depth of 16.7 meters. The deep hole penetrates into the underlying nonwelded tuff (Tunnel Beds).

Fourteen EX holes were drilled in the Heated Block Alcove. These holes will contain the guard heaters. Nine BX holes were drilled for permeability measurements and fracture characterization. Drilling has commenced on the remaining instrumentation holes.

Experiment Support--Routine tunnel support was provided for experiment installation. A number of tours were scheduled to the G-TUF. People on these tours included representatives of the Nuclear Regulatory Commission and members of the Rock Mechanics subcommittee of the American Society for Testing and Materials.

Instrumentation Alcove--The permanent Instrumentation Alcove was completed.

Ventilation System Improvement--The 0.5-meter ventilation lines were replaced with 0.67-meter lines. This completes the ventilation improvements for the G-TUF.

Welded Tuff Experiment Preparation

Small-Diameter Heater--The first phase of the Small-Diameter Heater Experiment in welded tuff was started and completed. This phase of the experiment consisted of two heating periods in which the power was set at 800 watts. The initial heating period lasted for 21 days and 16 hours. The heat was turned off when it had been established that near steady-state temperatures had been reached. A primary objective of the first phase of the test was to monitor the possible water migration into the annulus around the heater and evaluate its effects. Results showed that moisture did migrate into the emplacement hole, but did not accumulate in measurable quantities.

The results indicate that liquid water was present at the base of the heater during the early portion of the test. Several phenomena were indicated by the results. The first is that the thermocouples on the bottom of the heater appeared to go through several stages. The first is the initial heat rise. The second is the dropping of the temperature to a plateau of approximately 150°C for approximately 18 hours and then a rise to temperatures over 200°C. This behavior contrasts with that of all other heater thermocouples since their behavior was similar to that of the heater-element curves.

The double-inflection-point behavior of the lowest part of the heater skin is consistent with the indication of moisture buildup near the 0-level water indicator. The thermal behavior of the heater skin is attributed to an increase in the "effective" thermal conductivity due to water buildup in the annulus around the heater (i.e., initially the bottom of the heater is in a water bath). After approximately 30 hours, this moisture vaporized, and the "effective" thermal conductivity became that of the rock. The vapor that collected in the hole appeared to migrate towards the cooler region above the heater and a small amount condensed in this area upon cooldown. No water collected in the bottom of the hole during cooldown.

It was thought prudent to check this behavior. This was accomplished by flooding the hole for intermittent periods after a seven-day cooldown period. For the reference, the hole was fractured, except for the deepest 38 cm. Water was maintained at a standing depth of 1.8 meters for a cumulative period of 10 hours over a seven-day period. This meant that the lower 38 cm of the hole was continuously flooded, and the upper portion of the hole intermittently exposed to water.

On the fourteenth day after the heat was initially turned off, the hole was drained. The seven-day reheating phase was initiated on the fifteenth day. Three distinct differences are noticeable between the initial response and that on reheating. First, the 0-water level indicator starts operating at a higher voltage due to inability to remove all of the water from the bottom of the hole. The second point is that the overall shape of the water level voltage-time curve is similar to that in the previous figure, but that water is present for a shorter period of time. Finally, it is noted that the heater skin temperatures are similar to previous values, but do not show the initial rise, and drop and rise slowly while water is present. It is noted that the loss in voltage of the water level indicator again corresponds to the temperature rise of the heater skin.

These results support the interpretation that water does migrate into the emplacement hole and then vaporizes. The fact that the water vaporized earlier during the reheating cycle is attributed to the probability that only a small amount of water accumulated in the pore space in the fractured portions of the hole during the intermittent flooding due to the fractured and permeable nature of the rock in this area.

Unit Cell-Canister Scale--Instrumentation preparation for this experiment is the same as required for the Heated Block; progress is reported in that section.

Heated Block--Nine BX drill holes were drilled and three selected for use as reference holes within the block. Preliminary premeability measurements were made in a single fracture within the block. The fracture had a permeability of approximately 5×10^{-9} cm^2 (0.5 Darcy). This reference permeability will be used in evaluating the effects excavation, temperature, and stress.

The establishment of the reference permeability holes effectively located the heated block. The outline of the block was established; drilling was started and completed on the guard-heater holes.

Much progress was made in the preparation of the instrumentation for this and the Unit Cell Experiment. The preinstallation preparations and proof testing for the multiple point borehole extensometers have been completed. The USBM borehole deformation gauges have been heat treated and subjected to severe environmental checks. One was to expose the gauge to 200° steam for a period of 96 hours to ensure moisture proofing. The CSIRO hollow inclusion strain cell has proved satisfactory at ambient temperatures, but has not worked well at elevated temperatures. Proof testing techniques are being reviewed and possibly revised. A new design for pore pressure measurements is being developed. The design incorporated mechanical packers.

Fabrication of the heaters and flatjacks is complete. All components are to be assembled in August for installation after the slot-cutting phase.

Rocha Slot--Slot-cutting techniques have been reviewed, and a diamond-tipped chain saw added to consideration. A demonstration of slot cutting is to be scheduled during the fourth quarter. A flexible-edged flatjack is being designed and is to be proof tested during the same quarter.

Thermal Properties--Samples were submitted for measurements of both thermal expansion and thermal conductivity; partial results were received.

Thermal conductivity of these samples of welded, devitrified tuff from the heater hole used in the small-scale heater test was measured. The confined fully saturated thermal conductivity of these samples (based on a total of 18 individual measurements) averages 1.85 ± 0.03 W/m°C. Confined, dehydrated conductivity averages 1.46 ± 0.05 W/m°C. Both values are in good agreement with previous results. Accordingly, no further conductivity measurements in the welded, devitrified Grouse Canyon are presently being planned.

Bulk property measurements on the three samples of welded tuff indicate a range in porosity of only 0.11 to 0.16. Determination of the initial state of saturation was impossible, however, due to small sample size. Additional samples have been submitted for saturation determination.

Three samples of heavily zeolitized nonwelded tuff from Tunnel Bed 5 were submitted; samples were from the planned small-scale heater hole. The saturated thermal conductivity of two of the samples (based on 12 individual measurements) averaged 1.30 $\pm$ 0.03 W/m^{o}C, very slightly lower than average results for the heavily zeolitized tuffs from Yucca Mountain. Confined, fully dehydrated conductivites of the two samples (12 measurements), made a temperature of 200 to 260^{o}C, averaged 0.66 $\pm$ 0.04 W/m^{o}C, significantly lower than for zeolitized tuffs from Yucca Mountian, (approximately 0.9 W/m^{o}C). Upon cooling to ambient temperature, the two samples analyzed to date behaved quite differently. One (50HG#3-7.6-8.0) showed a decrease in apparent conductivity to 0.43 W/m^{o}C, perhaps due to contact resistance. The other (50H#3-44.1-4.5) showed only a slight decrease to 0.64 W/m^{o}C.

Bulk property measurements from Tunnel Bed 5 indicate both uniformly high porosity (0.49-0.50) and high initial saturation (greater than or equal to 0.9). The porosity is higher than that generally for the Calico Hills (0.33).

No confined thermal-expansion results are yet available for Tunnel Bed 5; samples have been submitted for testing.

Nonwelded Tuff Experiment Preparation

Small-Diameter Heater--The first phase of this experiment was scheduled for the third quarter, but it had to be rescheduled to the next quarter because of a delay in the delivery of extension wire.

Pressurized Slot--No activity.

Heated Slot--No activity.

1.4.2.1.3 Yucca Mountain Evaluation

Objective: To define, characterize, and evaluate the tuff strata underlying Yucca Mountain to determine their relative desirability and suitability for hosting a repository.

Definition of the preliminary functional thermal stratigraphy in Holes USW-G1, UE25a-1/b-1, and USW-G2 was completed. Zone IIB, which was picked to coincide as nearly as possible with the lower devitrified, densely welded "nonlithophysal" portion of the Topopah Spring Member, ranges in thickness from 25 to 88 meters. The lower boundary of this zone is generally distinct (except in USW-G2) and can be picked at the top of the basal vitrophyre, which is almost always present in this unit. The top of the zone, however, is arbitrarily defined here as the level at which lithophysal void space begins to exceed 10 percent. In USW-G2, which is quite near the source of the Topopah, this leaves only a thin horizon near the base of the unit. It must be stressed

here that the cutoff at 10 percent lithophysal void space is arbitrary and subject to revision. An effort is presently under way to assess the maximum reasonable lithophysal content that the waste-emplacement horizon can have from both a thermal and mechanical point of view.

It should be noted that Zone I, which was picked to extend from the base of the vitric caprock in the Topopah to the surface, is quite variable in thickness. The main reasons for this are: (1) Holes USW-G1 and UE25a-1/b-1 were drilled in washes while USW-G2 was drilled on the ridgeline; and (2) USW-G2, being near the source of the Topopah and younger tuffs, contains a much greater thickness of the younger tuffs than do USW-G1 and UE25a-1/b-1.

Data presently available are extremely limited in the upper portion of all holes except for Zone IIB. Thus, both bulk-property and thermal-conductivity data in the upper part of the tuff stratigraphy must be considered qualitative. In all localities, the maximum workable lithophysal content remains to be defined.

Three memos defining the functional thermal stratigraphy of the four potential emplacement horizons in Holes USW-G1, UE25a-1/b-1, and USW-G2 were completed and have been submitted to DOE/NV. The first of these memos, that dealing with the Tuffaceous Beds, has been upgraded to draft SAND-report status, is presently undergoing internal review. The other two memos will be similarly upgraded.

Measurement of thermal expansion within the Calico Hills in USW-G2 has been completed, and results from nine confined runs have been received. The tests were run at a confining pressure of 10 MPa and fluid pressure of 0.2 MPa to temperatures of approximately 90°C, above which fluid pressures were reduced to a slight vacuum. On cooling, the vacuum was maintained, so that the samples did not rehydrate. The results appear to fall into three distinct patterns. Samples at depths of 1,781, 1,974, and 1,852 feet contract 0.15-0.3 linear percent on dehydration to temperatures of 240°C. Heating was carried out at a rate near 0.5°C/minute. Mineralogical analyses, provided by Schon Levy of LANL, indicate that these three samples contain 60 percent or more total zeolite, with generally less than 10 percent quartz, and, except for Sample 1781, less than 10 percent feldspar. This type of contraction is quite similar to that seen in the Calico Hills from USW-G1, and from Tunnel Bed 5 in G-tunnel, and appears to be representative of the most strongly zeolitized intervals.

Results from an intermediate depth interval (2,185, 2,291, and 2,321 feet), within which contraction on drying is less, were about 0.1 linear percent. Mineralogical analyses indicate that these samples, while still being strongly zeolitized, contain 5 to 10 percent quartz, and between 10 and 25 percent feldspar. Thus, decreasing zeolite content and increasing quartz and feldspar appear to be coupled and decreasing contraction on dehydration.

Results from the deepest parts of the Calico Hills in USW-G2 (2,455, 2,650, and 2,696 feet) indicate contraction of a maximum of about 0.1 percent; this is similar to results obtained on samples from the overlying zone. However,

the deeper samples contract more rapidly on dehydration, and maintain almost constant length with subsequent increasing temperature. Mineralogical analyses indicate that the total zeolitization in this depth interval is less than above, being on the order of only 20 to 30 percent, while quartz and especially feldspar contents have increased markedly. Thus, there appears to be a rough but consistent trend towards a decreasing amount of zeolitization as a function of depth within the Calico Hills in USW-G2, coupled with a decreasing amount of contraction resulting from dehydration.

Predehydration expansion coefficients also appear to be somewhat sensitive to detailed mineralogy. The approximate degree of precision of the confined measurements is $\pm$ 1.5 x 10^{-6} $^{o}C^{-1}$, and the three samples from the upper portion of the unit expand at an average rate of 8.7 x 10^{-6} $^{o}C^{-1}$ before the onset of dehydration, the three intermediate samples at a rate of 6.2 x 10^{-6} $^{o}C^{-1}$, and the three deepest samples at a rate of 4.0 x 10^{-6} $^{o}C^{-1}$. If it is assumed in the absence of data that the predehydration expansion of the zeolites clinoptilolite and mordenite is on the order of 10 x 10^{-6} $^{o}C^{-1}$, then the decreasing predehydration expansion rate with increasing depth is consistently explained by the increasing feldspar content, since the reported expansion coefficient of alkali feldspars is 3 to 4 x 10^{-6} $^{o}C^{-1}$. Thus, decreasing zeolitization and increasing feldspar content with depth would correlate with both decreasing contraction on dehydration and a decreasing predehydration expansion coefficient.

In general, there is a marked coupling of dehydration-relation contraction and net compaction at the end of testing. Samples run at a vacuum of 0.1 MPa after dehyration, underwent 0.45-0.5 percent net linear contraction on cooling to ambient temperature. Samples 2291 and 2185 were subjected to a vacuum, while Sample 2321 was simply vented to the atmosphere on cooling. Most of the Contraction in Sample 2321 was reversible, with the final net contraction being only 0.5 percent. Samples 2291 and 2185, in addition to contracting less than shallower samples on heating, also underwent less net final contraction, 0.25-0.35 percent. Other samples were all subjected to vacuum, and underwent about 0.25 percent net contraction after cooling.

Testing of thermal expansion of zeolitized Calico Hills is only recently completed; results must undergo additional interpretation before they can be formally reported. To date, however, results appear consistent, and appear correlated with broad trends in mineralogical variation with depth.

Several additional thermal conductivity results for zeolitized tuffs have been received. Previously, 13 sets of results had been received for zeolitized ashflows at Yucca Mountain. These tuffs had an apparent zero-porosity thermal conductivity of 1.95 $\pm$ 0.18 W/m^{o}C, apparently independent of depth, formation, and lateral location. There was little apparent correlation between matrix conductivity and bulk properties, either grain density or mineralogy. Data from Yucca Mountain were collected as part of concentrated effort to characterize the zeolitized Tuffaceous Beds of Calico Hills; data from Hole SDH#3 in G-Tunnel were collected as part of site characterization for the G-Tunnel rock mechanics area.

Part of the intention was to determine if there was a significant difference in thermal conductivity between nonwelded ashflows and bedded/reworked sequences. The apparent matrix conductivity of the four new measurements on ashflow tuffs in USW-G1 and USW-G2 averages 2.41 ± 0.16 W/m°C, statistically larger than the value of 1.95 W/m°C arrived at previously, but not statistically different than the value of 2.37 ± 0.24 W/m°C calculated for the four measurements on samples from bedded/reworked zones. Thus, these results, which may cast doubt on previous conclusions about the apparent thermal uniformity of zeolitized tuffs, may also indicate that there is little or no significant thermal difference between nonwelded ashflows and many bedded/reworked intervals, so long as both are zeolitized. In comparison, the results from Tunnel Bed 5 indicate that, while the saturated conductivity of this unit is quite similar to that of the zeolitized Tuffaceous Beds of Calico Hills, the dehydrated conductivity of the tuff from G-Tunnel is appreciably lower, 0.6-0.7 versus 0.8-1.3 W/m°C. This appears to be due to the greater porosity of Tunnel Bed 5, approximately 50 percent, versus approximately 25 percent.

Finally, the results indicate that there is a consistent temperature effect on the dehydrated thermal conductivity of zeolitized tuffs. The first dehydrated thermal conductivity was measured at temperatures above those required for dehydration, i.e., between 200 and 260°C. The second dehydrated conductivity, which is only available for a total of five samples, was measured after cooling the test rig and sample to ambient temperature while still under confining pressure. In all cases, the reported thermal conductivity decreases with decreasing temperatures by from 9 to 44 percent of the ambient-temperature value. Results for sample SDH#3--7.6-8.0 are suspect; the average decrease conductivity of the other four samples is 17 percent of the ambient-temperature conductivity between temperatures of 230 and 30°C. Assuming this decrease to be linear, dehydrated conductivities of strongly zeolitized tuffs at 100°C should be about 8 percent lower than previously reported, since all previous measurements were made at temperatures at or above 200°C.

Measurement of thermal conductivity within the Tuffaceous Beds of Calico Hills is continuing, as are mineralogical analyses of tested samples. In addition, samples of commercially pure zeolite have been submitted. The intent is to estimate the extent and reasons for thermal variability within the unit. At present, results generally seem reliable to within ± 15 percent. It should be determined in the fourth quarter whether or not this variation is firmly correlated with mineralogy, or is due to nonresolvable uncertainties. Major additional work on the Tuffaceous Beds would be pursued after that time only if the Tuffaceous Beds were both selected as the target emplacement horizon and if sensitivity analyses indicate that ± 15 percent uncertainty in thermal conductivity is not acceptable.

Major emphasis in mechanical areas was placed in documentation of previous test results, largely as part of the SCR effort. Two SAND reports have recently been published dealing with matrix-mechanical results, and a third dealing with fractured or jointed samples. Sample preparation has been completed for the densely welded, devitrified Topopah, and testing begun. Preliminary testing will be completed in the fourth quarter.

A major area of concern is the need to estimate and/or determine the mechanical properties of lithophysal portions of the Topopah. As a first step in this effort, a preliminary model has been developed in which mechanical properties "degrade" with lithophysal void space in a manner described for spalling of ductile metals. Using this approach, the estimated Young's Modulus and Poisson's Ratio for 15 percent-lithophysal Topopah are 20 GPa and 0.26, as opposed to 28 GPa and 0.28, respectively, for nonlithophysal material. Further work on the effects of lithophysae on both elastic properties and failure stresses within the Topopah is required. It will be carried out from both a theoretical and testing point of view; the overall objectives being to estimate the maximum "usable" lithophysal content within the potential emplacement horizon in this unit.

1.4.2.1.4. Horizon Performance Analysis and Geotechnical Evaluation

Objective: To recommend a tuff horizon or zone at Yucca Mountain that is the most favorable on the basis of geotechnical considerations for the development of a repository and to perform the follow-up detailed geotechnical evaluation of the selected horizon.

Activities for this task are reported in Tasks 1.1.5 and 1.4.2.1.3.

1.4.3 EQUIPMENT DEVELOPMENT

(No NNWSI work funded this fiscal year.)

1.4.4 INSTRUMENTATION DEVELOPMENT

(No NNWSI work funded this fiscal year.)

1.4.5 REPOSITORY SEAL DEVELOPMENT

Objective: To develop and test repository sealing methods for an underground repository located in tuffaceous media on or near the NTS.

1.4.5.1. Repository Sealing

Objective: To develop repository sealing concepts for tuff, including the seal material requirements, specifications, and emplacement techniques which will ensure that repository integrity will not be breached as a result of the sealing method enployed, and to perform field testing of the concepts developed.

Shaft and Borehole Sealing

The purpose of this study is to evaluate the short- and long-term chemical stability of sealing materials in the felsic tuff environment of Yucca Mountain. A three-year program plan has been developed. Initial tests for the purpose of screening a number of potential sealing materials include agitated-vessel studies to accelerate the reaction at 25 to 200°C. Samples will be examined before and after tests by X-ray diffractometer, optical

microscope, scanning electron microscope, and electron microprobe. The most promising candidates for sealing materials will also be tested in a temperature gradient circulating system. Rock and cement permeability tests may also be run at controlled temperature and pressure. Field tests of selected materials will consist of flow tests in which a fluid pressure differential is imposed on a sealed borehole. Such tests will include observation of chemical reaction in the disturbed region adjacent to the borehole in addition to that in the sealed hole. The hole will later be overcored and dissected; the rock and sealing material will be examined in detail for chemical interaction by the methods described above.

Two samples of G-Tunnel were obtained from Sandia National Laboratories so that geochemical testing can be initiated on the same material that the Waterways Experiment Station is using to determine mechanical properties for Sandia.

A visit was made to the Materials Research Laboratory at Penn State at State College, Pennsylvania, to discuss the sealing studies being done at that laboratory and explore the feasibility of further work during FY 1983. The geochemical part of such work would include the studies of the chemical interaction of felsic tuff with sealing materials in agitated vessels and in circulating systems, followed by detailed examination of the experimental samples to determine the nature of sealant/rock interaction.

Repository Sealing Performing Assessment

Using a systems approach, the repository sealing issue has been divided into three subcategories: (1) what function is to be accomplished by the component(s) of the compositor one-material seal; (2) why these functions are required, i.e., the overall repository and sealing subsystem performance objectives; and (3) how well these functions are met by comparing their adequacy to standards established by performance assessment calculations. The performance objectives have been structured into an objectives tree. The primary objectives in addressing the sealing system objective are optimizing the isolation capability of the system, minimizing the cost in emplacing seals, the maximizing the confidence in the sealing system. Each of these can be further subdivided until individual items result. The functions served by seals can be reduced to: control of gas and fluid flow, sorption of radionuclides, and enduring process and event degradation (both physical and chemical). Three zones in which the seal could be emplaced are the core barrier, interface zone, and the disturbed zone. The materials historically considered are grouts, concretes, clays, zeolites, native rock, native rock in slurry, and metals. An understanding of a materials versus functions matrix would enable one to select the appropriate material(s). Another aspect which is being factored into the repository sealing program is the development of material which will meet all or almost all functions served by seals. An integral part of the systems approach is the performance assessment calculation which can focus on the major concern of the sealing subsystem or refine seal design. Before calculations can begin, however, it is important to categorize the types of penetrations and the environment into which the seal will be placed. The types of penetrations fall into two categories.

The characteristics of the host environment are being incorporated into the physical model (including the geohydrologic and physical seal model) as data from other portions of the NNWSI project are received. Ranges of values will be considered where data are scarce or are of poor quality. For example, the uncertainties in the geohydrology have necessitated using a range of values for gradient of the groundwater table between 0.0025 m/m to 0.25 m/m.

To reasonably assess the appropriateness of various seal designs in specific environmental conditions, it is necessary to develop seal design scenarios. This has been completed. Several scenarios are possible, ranging from no failure of seals where the seals are theoretically perfect to no seals, both of which are at the opposite range of consequence potential. More realistically, there are three additional scenarios which can be modeled: seal fails catastrophically, seal fails gradually as designed, and seal fails gradually (but at a faster rate than designed). Modeling of the most reasonable scenarios will continue over the next quarter. To further narrow down the scope of the problem, one stratigraphic cross section will be used and the types of penetrations categorized.

To understand the extent of the sealing necessary, thermal-hydrologic calculations are being done to determine the number and properties of plugs needed to minimize perturbations to the local and regional groundwater flow at the proposed waste repository locations at the NTS. Two waste emplacement concepts are being considered: (1) floor emplacement in drifts and (2) in long "torpedo" tubes between drifts. In addition, two layout orientations, one parallel and another perpendicular to the hydrological pressure gradient, are being considered. As part of the analysis, a parametric study, varying rock properties, seal properties, and hydrologic gradient is being performed.

The two-dimensional, finite element code Mariah solves complex heat and mass flow through saturated porous media. Initial calculations have been done using Mariah to estimate the groundwater flow in the area adjacent to a 5 x 7- by 450-meter drift. The rock surrounding the drift was assumed to have constant properties and the draft was filled with material or permeability ranging from 10^{-14} m^2 to infinity (simulating no fill at all). With a rock permeability of 10^{-15} m^2 (the approximate mean permeability of the saturated Yucca Mountain stratas), significant deviations in the streamlines occurred unless the fill permeability was within an order of magnitude of the rock permeability. The boundary conditions at the top and bottom surfaces of the problem affect the streamlines although the distance from the drift to either surface is 400 meters. This implies that the actual strata dimensions and permeabilities could also change the flow pattern.

The cross flow streamlines for a drift perpendicular to the driving gradient are accurate representations of the flow over the center of a long drift where end effects are not important. Very little change in the streamlines can be seen beyond a few meters from the drift.

Preliminary nonisothermal calculations have been done to estimate the effects on crossflow past a drift or borehole emitting heat from waste canisters. The results of these calculations imply that there is little effect in low

permeability rock (10^{-16} m^2) of the heat source on the flow or vice versa. This may not be the case in strata with higher permeability or with flow parallel to the drift or borehole.

1.4.6 GENERIC REPOSITORY ENGINEERING

(No NNWSI work funded this fiscal year.)

1.4.7 REPOSITORY CONCEPTUAL DESIGN

Objective: To develop a conceptual repository design which will serve as the basis for a Title I design.

1.4.7.1 Preliminary Data Package Development

Objective: To prepare data and analysis summaries and to perform systems analyses of geotechnical information and computer models to be used for developing the design guidelines for a conceptual repository design.

The loss of drilling fluid study regarding drill hole USW-G1 which was discussed in the previous quarterly report has been completed. Work during this quarter consisted of:

-- A technical review of the study by a reservoir engineering firm, Completion Technology Co., Houston, Texas.

-- Revision and addition to graphic data development.

-- Preparation of a draft of the technical report on the study.

Regions of high fracture density and low rock quality designation correlate with zones in which large quantities of drilling fluid were apparently lost.

A consideration that cannot be adequately addressed by the study is the hypothesis by M. Zoback, USGS, that hydraulic fractures, induced by drilling operations, took up the drilling fluid. The final report will be released in the near future. The draft is presently being reviewed and edited.

1.4.7.2. Conceptual Design Development

Objective: To develop a conceptual repository design for a specific repository horizon which will serve as the basis for the Title I design and which will provide direction for the location of the Exploratory Shaft.

Conceptional Design Guidelines for an NWTS Repository in Tuff

The Design Guidelines document is being assembled by Los Alamos Technical Associates (LATA) from data, discussions, investigation reports, and other SNL staff materials. Division 9761 staff have provided an extensive review of this document, and several meetings have been held with LATA by SNL to develop the final format, content, and style of the Guidelines. The present rewrite

objective is to incorporate SNL recommended changes with a proof copy to be delivered to SNL by July 15, 1982.

The Guidelines consists of three sections, first the Repository Description and Design Assumptions by SNL Division 9761 staff, second the Repository Design Work Breakdown Structure (WBS) and finally, the Design Input Data Base. The latter Data Base has been developed for the first three or four levels of the WBS and provides design objectives, deliverables criteria, codes and standards, data and information, and references for the five WBS elements of Waste, Site, Operations, Special, Special Equipment, and Special Systems.

It is intended that the Repository Conceptual Design will be executed within the framework of the Work Breakdown Structure and these Guidelines. This framework will provide a management control document which will continue to be developed through subsequent stages of the project. It is intended that the WBS will be used as the format to organize the request for proposal for architect-engineer (A-E) services for the Conceptual Design. It will be the basis for evaluating proposals for A-E selection, and it will be the basis for management of the engineering effort. As the project proceeds, the WBS will be refined and developed to reflect new developments and definitions. This process should greatly assist the development of a conceptual design that can be easily reviewed for completeness and credibility and will assist the production of definitive costs and schedules for planning future repository work.

Heat Transfer and Thermomechanical Analysis

Heat transfer and thermomechanical analysis of the thermal effect on the host rock due to waste emplacement are under way. The three models used to evaluate the emplacement techniques were described in detail in last quarter's report. Briefly they are:

-- Room and pillar with waste placed vertically in room invert wells.

-- Waste placed horizontally in pillar between two parallel drifts.

-- Waste placed in self-shielding casks stacked on room invert.

During this quarter, two studies have been started. Both studies address the effects obtained considering the horizontal emplacement model.

The first study by R. Peters, SNL 9762, considered several options for extraction ratio, gross thermal load, emplacement separation, and buffer length. (The buffer is a plug of material, with properties similar to the host rock, used to isolate the emplaced waste containers from the wall surface of the access adits.) Using these options, temperatures were determined at the wall surface and at locations within the pillar as functions of the after-waste emplacement.

The second study by L. Branstetter, SNL 5521, determines pillar interior temperatures, resultant rock stresses, and joint crack width changes as

a function of time after emplacement. A plane strain assumption was used and a vertical joint pattern with cracks at one-meter spacing was assumed. This study has not been completed.

Exploratory Shaft Location

The task of locating the Exploratory Shaft and establishing the method of construction took a large portion of time this past quarter. The effort would have been even larger (or not possible) without the support of the three-dimensional computer graphics capability. Numerous general layouts of facilities, drainage basin area, environmental effects, geologic information, etc., were either generated, digitized, and scales adjusted, overlays of different parameters assembled, or in some other ways manipulated.

During the course of this effort, considerable new data on the location and shape of the repository block came to light. The earlier work on preliminary repository configuration by Milloy and Young is now obsolete. Insofar as practical, corrections will be incorporated in that report and published. The full incorporation of the block changes will be incorporated in a revised configuration next fiscal year.

1.4.8 REPOSITORY PERFORMANCE EVALUATION

(No NNWSI work funded this fiscal year.)

1.5 REGULATORY AND INSTITUTIONAL

Objective: To assess and document the safety and environmental characteristics of a repository system in a manner which meets anticipated NRC licensing requirements and the requirements of the National Environmental Policy Act (NEPA).

1.5.1 REGULATORY BASELINE

Objective: To ensure that NNWSI licensing assumptions and plans are consistent with NWTS assumptions and plans.

This task has no reportable progress.

1.5.2 LICENSING APPLICATIONS

Objective: To plan and coordinate the preparation of licensing-related documentation.

Part A Chapters 1 and 2 were provided by the ONI contractor (Ebasco) but are incomplete and will not be ready for NNWSI review until August or September.

Draft sections of Part B of the SCR were received by the TOC from the project participants. These sections will be reviewed by the TOC for consistency of technical content. Based on this review, revisions will be made cooperatively by NNWSI technical personnel, the TOC, and, perhaps, third party editors.

An early draft hierarchy of issues to be addressed by Part C of the SCR was developed by the TOC and reviewed by the TIG. The hierarchy distinguishes among Key Issues, subordinant Issues for each, and Information Needs to resolve each issue. Descriptions of Information Needs will relate planned work elements to the currently perceived licensing requirements. Contributing authors to Part C provided inputs in varying degrees of completeness. In view of general uncertainty regarding the amount of detail to be provided, extensive revision is under way. To enable effective integration, a streamlined issues hierarchy is being completed that will reduce redundancy but allow for grouping of similar work elements which satisfy common information needs. A more coherent and usable document should result.

1.5.3 NEPA DOCUMENTS

Objective: To plan and coordinate the preparation of the NEPA documentation.

Activities were scoped, scheduled, and networked for an Environmental Assessment (EA) for the Exploratory Shaft and other site characterization activities.

An annotated outline was developed and discussed with WMPO/NV. Also, the outline was discussed with archaeology, atmospheric, and biological contractors

to determine their inputs. Their inputs were received and the EA is being drafted. Initial efforts have been in the description of the "affected environment." The geology, hydrology, meteorology, and energy/mineral resources subsections have been completed.

A list of required additional inputs for the EA (with critical dates) were developed and transmitted to WMPO/NV. A request for interpretation of five legal questions and eighteen policy/procedure questions was prepared and transmitted to WMPO/NV.

1.5.4 COMMUNITY AND INSTITUTIONAL LIAISON

Objective: To inform and coordinate appropriate NNWSI activities with the affected community and government institutions.

This task has no reportable progress.

1.6 TEST FACILITIES

Objective: To ensure the availability of test facilities and equipment necessary to support the research, development, and demonstration activities of the NWTS Program.

1.6.1 SALT FACILITIES

(Not applicable to the NNWSI.)

1.6.2 GRANITE FACILITIES

1.6.2.1 Climax Test Facility

Objective: To provide the support services needed to operate and maintain the Climax Test Facility.

Fuel Handling Operations

Detailed planning for Fuel Exchange No. 3 is under way. The planned activities are more extensive than usual and involve a total of four spent fuel canisters. The purpose of each movement is outlined in the following paragraphs:

a. Retrieve fuel assembly S/N D04 from storage hole CEH11 and return to the E MAD lag storage. This assembly was selected to comply with a HEDL recommendation and this assembly will be positioned at the E-MAD Facility for removal of the Materials Interaction Test train in late August.

b. Relocate S/N D18 from storage hole CEH16 to CEH11. This transfer is required to maintain a "matched set" of assemblies in the central repository model cell portion of the test array.

c. Remove S/N D34 from storage hole CEH01 for examination and reemplacement. This activity is planned based on thermal data which indicates that water was in contact with the canister. While it is not essential that this examination be done at this time, the incremental effort will be minimal. If any remedial action is indicated, this will maximize available planning time prior to initiating the test completion operations in FY 1983.

d. Transfer S/N D22 from E-MAD to storage hole CEH16. This assembly is currently in storage in E-MAD Drywell 5 (emplaced September 4, 1980). Retrieval to the Hot Bay and replacement of the E-MAD shield plug with a Climax plug will be required prior to relocation to the SFT-C. This assembly is the only D-series fuel available for this exchange as HEDL desires to keep D06 (moved to the E-MAD Facility in October 1981) available for possible MIT removal later this year.

In preparation for these activities, two additional Technical Operating Procedures (TOP-005 and -006) have been drafted, reviewed, and approved by the LLNL-N Resident Manager. DOE/NV concurrence was received late this quarter. The procedures will be printed and distributed in early July.

Preparation of a detailed daily activities schedule is in progress. The activities are presently planned to occur the weeks of August 9 and August 16, 1982. The first week will include demothballing and a dry run. The second week will focus on spent fuel handling. The schedule is not yet firm because of recent changes in weapons test program schedules at the NTS.

The STV hydraulic systems were exercised at the Area 25 storage area during May using manual control valve actuation. No problems were found. Hydraulic fluid samples were taken for water content analysis.

Plans to develop an STV control panel to be used at the Area 25 storage area were previously reported. This would reduce project costs by eliminating the need to move the STV to the E-MAD Facility and mobilize a work crew there. These plans have been curtailed based on guidance for a three-year spent-fuel storage phase at the SFT-C. Cost savings would not be realized during the brief time remaining.

As indicated in item c. above, the canister in CEH01 has possibly been damaged by contact with corrosive groundwater. Samples of gas have been obtained from the rock/liner and liner/canister annuli to investigate this possibility. Analysis for helium indicates no elevated level of this gas. Analyses for HT and HTO have been inconclusive to date, so additional samples are being obtained.

A draft checklist has been prepared to be used in sampling gases, liquids, and corrosion products obtained during inspection of CEH01.

Data on the thermal history of SFT-C spent fuel assemblies were assembled and forwarded to the PNL Spent Fuel Management Program. Only the time period when the fuel was in LLNL custody was addressed.

Facilities Maintenance

The refurbishment of ventilation fans was completed this quarter. This required replacement of fan shaft bearings, drive pulleys, and belts on one unit and pulleys and belts on the second unit. A replacement flowmeter turbine was ordered following tests by REECo Industrial Hygiene and LLNL personnel which indicated the jeweled bearings in the flowmeter were badly worn. The unit was installed and preliminary calibration was performed.

The air-conditioning (A/C) system for the DAS trailer malfunctioned with both units ceasing to work. The units are now operating, but the cause of failure is as yet unknown. A potential source of problems is the "lead-lag" configuration of the two units which frequently causes them to fight each other in the heating/cooling and humidify/dehumidify cycles. The units will be rewired to eliminate this situation. A company (POMONA) service engineer visited the

SFT-C site the first week of May to thoroughly examine the units. A report of his findings has been received.

The humidifier on these A/C units also malfunctioned. Replacement parts are on order and will be installed in July.

Thermal and Thermomechanical Modeling

The results of previous calculations were edited for incorporation in the project interim report where data and calculations are compared.

Evaluation of the effect of boundary conditions on modeling results is being pursued on two fronts. First, the ADINA/ADINAT codes are being used to analyze the SFT-C response during the heated phase of the test. Some difficulties have been experienced in using these codes on the very large meshes employed in the boundary effects calculations. The source of the problem has been identified and the code is being modified to facilitate solving the larger problem. Second, the mine-by problem is again being examined in view of how boundary conditions may influence calculational results. Several problems have been set up and preliminary results are being analyzed.

Field Instrumentation

Displacement Measurements--Normal instrument maintenance and periodic manual tape extensometer readings were continued this quarter. Additional tape measurements were made weekly to augment the data set during the ventilation effects test.

Four of the replacement potentiometers on the vertical rod extensometers experienced failures. The problem is localized in the head assemblies which are sealed to maintain the ambient environment of the extensometer. Nearby units which are nitrogen purged and evacuated show no indications of failure. Initial examination of two of the resistive elements with an SEM indicates fracturing of the elements. The cause of fracturing is currently unknown but is under investigation.

The first step of this investigation was to sample the gases present in the head assembly. Two types of samples were taken: gas and buffered water through which a large volume of gas had been bubbled. These samples have been shipped to LLNL for analysis.

One of the original linear potentiometers on a rod extensometer also appeared to fail after 28 months of service in the moderately heated zone. Field inspection and cleaning of the resistive element of the potentiometer permitted returning it to service. Some debris or moisture apparently shorted the unit out, producing the observed readings which to date have been indicative of failures. This condition has occurred on two other units in previous months and appears to be unrelated to the catastrophic failure of other potentiometers reported previously.

Superinvar Testing--The coefficient of thermal expansion (CTE) of samples of Superinvar used in the G-series rod extensometers has been determined by the Fabry-Perot technique. This work was completed under contract to LLNL by S. Jacobs of the University of Arizona. Three samples of the material (1/4-inch-diameter by 4 inches long) are oriented vertically and separate the etalon mirrors. Three such assemblies (nine pieces) were tested. The test method involves locking a tunable laser to the etalon resonant frequency and comparing the laser frequency with that of a frequency-stabilized laser. A temperature change produces a change in sample length ΔL which is observed as a frequency change $\Delta f = -(f/L)\Delta L$.

The samples exhibited very low CTEs in the range 30-80°C. The CTE of the first test specimen is about -40×10^{-8}/°C at 20°C, crosses to zero at 60-70°C, and is about $+20 \times 10^{-8}$/°C at 90°C. Testing of the second specimen revealed a similar "U-shaped" CTE curve but without the zero crossover. The effects of thermal cycling and baking at elevated temperature were examined and indicated significant hysteresis under certain temperature cycling conditions.

Acoustic Emissions--Monitoring of acoustic emissions (AE) and wave propagation (P and S) characteristics continued this quarter. AE activity continued at the rate of one to two events per week. The events were confined to the east end of the test area, mainly in the north and south walls.

From spectral analysis of these events, the predominant frequencies are from 9 to 12 kHz with source sizes of several centimeters. The stress drops are several tenths of bars to a few bars, indicating normal rock breakage.

No AE activity was recorded as a result of the USGS hydraulic fracturing experiment. Activity was detected when sleeve fracture tests were performed.

Weekly monitoring of relative P amplitudes and S/P amplitudes continued. An equilibrium point seems to have been reached. The stability of AE19 relative to AE3 and 5 S/P amplitudes may be due to the stronger signal at AE19 relative to AE3 and 5. However, the AE3 S/P ratio is still higher than AE5, which was not the case prior to spent fuel insertion and heater activation.

The automatic seismic processor (ASP) has been operating continuously throughout the quarter. Several PROM failures occurred, but this was probably due to "infant mortalities." None of the failures caused any delay in the data collection. ASP has performed as specified to date. However, problems associated with the RCA 1802 assembly language, i.e., unusual I/O format, relatively slow computational speed, and limited precision, are problems that could become cumbersome in a daily operation. These problems have been mainly solved with version 4.0 of ASP by utilizing a DEC LSI 11/23. This provides larger memory and greater speed and flexibility.

Spent Fuel Dosimetry--In a move to reduce the variability in radiation dose-to-granite measurements, EG&G was directed to perform additional calibration studies with the lithium-fluoride thermoluminescent dosimeter (LiF TLD) material.

These elevated temperature calibrations of the lithium-fluroide TLDs were completed this quarter. Using the new mercury vapor TLD reading device, the 247 nm peak was extended to a range of 10^3-10^7 rads. This peak, coupled with the 374 nm peak which was found to be temperature insensitive, permits reanalyzing the dose measurements reported last year. The current calibrations indicate severe temperature sensitivity in the 443-nm peak which explains the broad range of error found in last year's analysis. These results will be applied to all data acquired to date which will be reported later.

Dosimeters for short-term (4-5 hours) measurements of dose have been prepared and calibrated for deployment during the August fuel exchange. Magnesium borate and calcium fluoride TLDs will be used. These measurements are being made to better understand (and hopefully eliminate) sources of error due to temperature and time annealing of TLD response.

Site Characterization

Both the core logging and field mapping fracture data bases are essentially complete at this time. A report on the former was submitted to DOE/NV this quarter and the latter has been recently published.

A USGS-developed fracture analysis and plotting computer program has been implemented on the LLNL computer system. This tool is being used to graphically present and analyze the acquired data bases.

The USGS (W. Ellis, J. Magner, and D. Kibler) completed hydraulic fracturing studies at the SFT-C. Tests in the horizontal borehole (UG-03) progressed as planned. In several locations, water injected in the borehole escaped to the surface of the tail drift and heater drift through interconnected geologic features. Tests in the upper section of the inclined borehole (UG-02) were successful, but the cable supporting the packer assembly failed, allowing the packers to fall down and lodge in the hole. Efforts to recover the packers were unsuccessful.

A campaign of in situ stress and modulus measurements was undertaken by Ö. Stephansson of the University of Luléa, Sweden. This technique, which is in the developmental stage, employs the Colorado School of Mines pressure cell to "sleeve fracture" the rock. Tests were performed in two boreholes. A combination of high tensile strength and secondary principal stresses resulted in only one successful fracturing test. Modulus determinations were successfully obtained. Results of this work will be reported by Stephansson in an ONWI report.

Ventilation Test

The ventilation effects tests were initiated this quarter. Data have been acquired during the first three phases of the test: two fans drawing air through all three drifts, two fans drawing air through only the canister drift, and "natural" ventilation with both fans turned off. The fourth and final phase, no ventilation, will be initiated July 2. During this phase of

testing, access to the underground facility will be strictly limited to essential personnel based on LLNL-N Health and Safety recommendations. Additional measurements have been made during all four phases of the ventilation tests to provide data to better understand the thermal sensitivity of selected instruments, the mode of ventilation in the drifts, the amount of heat removed as a function of ventilation rate, and the emanation of radon gas from the granite. These data will be analyzed and reported later.

Data Acquisition System

During this quarter, overall system reliability was 92.9 percent. Several major hardware failures occurred as discussed below. The recently developed "Bus Extender Switching Network" was instrumental in minimizing total system downtime and, hence, loss of test data.

Failure of the computer Node 100 disc drive required returning the drive to H-P for servicing. The source of the problem was a malfunctioning disc head servocontroller. The unit has been repaired and has functioned normally since early June.

Two Node 100 bus extenders and a digital voltmeter (DVM) also malfunctioned this quarter. The failures appear to be the result of an electrical storm which, in addition, caused a temporary loss of power at the site. Spare units were used to replace the failed units which were returned to the manufacturer for repair. A second DVM exhibited out-of-specification performance late in the month and was also replaced and returned to the manufacturer for repair. The problem with the DVM was limited to four-wire resistance measurements.

A problem in two scanners continues to occur sporadically. The transient nature of the problem has made diagnosis and repair elusive. The consequence of this problem is minor since the few data records which are affected are readily identifiable as erroneous. A special program was written to verify that the problem is localized to the two scanners.

Data Management System

Data tapes covering the period of mid-April through June have been received in Livermore. Initial processing is complete. A total of 5.9 million records have now been acquired for analysis.

Internal documentation of the binary tape read program (BREAD) was completed this quarter.

The major data management and processing activity this quarter was preparation of graphical output for incorporation in the SFT-C Interim Report.

Test Completion Planning

Test completion planning activities were initiated this quarter. In accordance with verbal guidance from DOE/HQ, a three-year spent fuel storage phase is presumed, with retrieval in April-May 1983. A draft completion schedule

has been prepared and forwarded to DOE/NV and V. Der, DOE/HQ. A draft critical path method (CPM) chart has also been prepared to aid internal planning.

Technical Reporting and Public Information Activities

Reports in publication process this quarter:

-- Heater Test No. 1, Climax Stock Granite, NTS; D. N. Montan and W. B. Bradkin, UCRL; in preparation.

-- Thermoluminescence for Self Dosimetry in Climax Stock Quartz Monzonite; R. C. Carlson, UCRL-86627; in preparation.

-- The Effect of Gamma Irradiation on the Strength of Climax Stock Quartz Monzonite; W. B. Durnam, UCRL-87475; in preparation.

-- Spent Fuel Test--Climax Data Acquisition System Integration Report; R. A. Nyholm, W. G. Brough, and N. L. Rector, UCRL-53304; in preparation.

-- Rock Core Logging Technique, Spent Fuel Test--Climax, Nevada Test Site; D. Wilder and J. Yow, UCRL; in preparation.

-- Spent Fuel Test--Climax Technical Measurement Interim Report, Fiscal Year 1981; W. C. Patrick et al., UCRL; in preparation.

Reports published this quarter:

-- Instrumentation #1: Identification, Design, Calibration, and Installation of Instrumentation for an Experimental High-Level Nuclear Waste Storage Facility; W. G. Brough and W. C. Patrick; UCRL-53248.

-- Instrumentation #2: Identification, Evaluation, and Remedial Actions Related to Transducer Failures at the Spent Fuel Test--Climax; W. C. Patrick, R. C. Carlson, and N. L. Rector; UCRL-53251.

SFT C Tour Summary

The following tours were conducted of the SFT-C site during this quarter:

4/1: American Chemical Society (90)

4/1: K. Wolfsberg (LANL), 1 German, 1 Canadian, and 2 University of Arizona students (5)

4/2: D. Miller and John N. Wilford, New York Times (2)

4/5: R. Duncan, R. Nelson, and Maurice Katz, Deputy Director for Military Application (3)

4/5: Florian Maldonado (USGS) and six visitors (7)

4/8: M. Gates, R. Nelson, and Benard C. Rusche, Special Assistant to the Secretary for Programs and Policies; and Charles E. Kay, Staff Assistant, Office of the Secretary (4)

4/19: Thomas O. Hunter, SNL; and Jurgen Krekeler, German citizen (2)

4/23: M. Gates, R. Nelson, and Jan W. Mares, Acting Under Secretary; and William M. Lamb, Executive Director, Office of Assistant Secretary for Defense Programs (4)

4/23: J. Moroney, Nuclear Systems Division; Dick Smale, LANL; and Subworking Group C of the Joint Working Group (6)

4/26: J. Gilpin and P. Marshall Ryan, Controller; and Elizabeth E. Smedley, Acting Director of Budget (3)

4/26: G. Larson and LLNL visitors (5)

4/27: J. Boyer, OPA, and Jean McGarry, SSD; and members of the Indian Springs PTA (62)

4/27: R. Nelson and James R. Richards, Inspector General (2)

4/28: S. Bolling, L. Skousen, NTSSO; and the American Society of Civil Engineers (90)

4/29: R. Stearns, EAD; and the University of Nevada, Las Vegas, Engineering and Geology class (45)

4/29: C. Sanford, LLNL; and Integrated Contractors (10)

5/3: D. Miller, OPA; R. Ide, S. Blackwell and W. Shuler, LLNL; and Richard H. Thompson, Time, Inc. (5)

5/5: D. Miller, OPA; and Atomic Industrial Forum Press Group (10)

5/6: R. Nelson and J. Erich Evered, Administrator, Energy Information Administration (2)

5/14: M. Gates and French engineers (16)

5/19: J. Moroney, HPD; and Kent Holmes, DOE/HQ (2)

5/19: Joint Atomic Intelligence Committee (20)

5/19: B. Nelson, LLNL; and Battelle (5)

5/20: D. Jenkins, OPA; and Chapter V of the Philanthropic Education Organization (45)

5/24: M. Kunich, D. Jenkins, and Atomic Industrial Forum (45)

5/24: J. Gilpin, R. Uehara, and Andrew D. Eppelman, Director, Manpower Resource Management; Elliott P. Roberts, Management Analyst, Organization Planning and Management Division; Owen B. Johnson, Program Analyst, Defense Programs Division, DOE/HQ; and John D. Bateman, Director, Personnel Division, Richland Operations Office (6)

5/26: B. Boland, DOE, and Low-Level Waste Research & Development Program Personnel (10)

5/27: C. Costa, D. Miller, and EPA Off-Site Monitors (30)

6/3: M. Kunich, Texas residents, and Lieutenant Governor's staff (8)

6/3: Robert L. Hammon, General Manager, EG&G Energy Measurements Group; Harold D. Cunningham, General Manager, Reynolds Electrical & Engineering Co., Inc.; and 10 EG&G executives (12)

6/8: R. Zimmerman, SNL; Zdzislaw T. Bieniawki, Republic of South Africa; and 4 engineers (6)

6/14: R. Duncan; D. Miller; C. Costa, EPA; and Rachel Miners (45)

6/16: M. Gates, R. Nelson, W. Kenneth Davis, Deputy Secretary, and John F. Bagley, Aide (4)

6/18: H. Melancon, Wolfram A. Wiest, and Hans C. Gujer, Bernische Kraftwerke AG, Switzerland (3)

6/24: R. Nelson; Stephen L. Jones, Administrative Assistant and Chief of Staff to the Secretary; and William A. Neustadt, Staff Assistant to the Secretary (3)

6/24: D. Vieth, G. Dixon, and USGS personnel (6)

6/25: J. Lytle and G. Armantrout, LLNL; and Ernst Zurflueh, NRC (3)

LLNL conducted 37 tours on 25 separate days for approximately 625 people.

1.6.3 BASALT FACILITIES

(Not applicable to the NNWSI.)

1.6.4 TUFF FACILITIES

1.6.4.2 Exploratory Shaft

Objective: To provide access to and to further define potential repository horizons in tuff via an Exploratory Shaft.

It appears that the DOE will authorize accelerating activities to allow drilling of the Exploratory Shaft (ES) six months earlier than previously planned. Some of the major milestones are shown below.

	Accelerated Schedule	Planned Schedule
Spud principal borehole	7/82	Not established
Start shaft drilling	3/83	9/83
Complete mining and start horizontal borings	4/84	2/85
Submit site recommendation report	4/85	?/87

The accelerated schedule is based upon the assumptions that the Test and Evaluation Facility will not be constructed at the NNWSI site and that the unsaturated horizons will be investigated first with the capability to extend the ES to the saturated horizons, should the unsaturated zone be found unacceptable.

The ES activities are proceeding on the basis that shaft construction will start in March 1983, although an official decision has not been made. Four key decisions that must be made before detailed design of the ES can proceed very far are (1) ES construction method, (2) ES location, (3) ES depth, and (4) number of breakouts. An ad hoc working group was established in April 1982 to identify a mechanism for making a recommendation on the first two decision issues. This group was charged with the responsibility for implementing the decision-making process and submitting its recommendations to the Technical Overview Officer (TOO). The findings of the committee concerning the construction method have been forwarded to the TOO recommending that the shaft be conventionally sunk. The committee determined that several sites can meet scientific and constructibility criteria and recommended a site located at about 4,150 feet elevation in the wash containing test hole UE25a-6.

The ES design and procurement activities will be initiated by Los Alamos by transmitting design criteria letters (DCL) to DOE/NTSSO, who will, in turn, approve and transmit them to the appropriate NTS support contractor. Two DCLs have been prepared and issued. The first authorizes preparation of specifications for breaking tongs, communication shelters, a mine cage communication system, and electrical transformers. The FY 1982 capital equipment funds are available for these items. The second DCL authorizes preparation of specifications for the main hoisting system.

A draft Program Management Plan was submitted to DOE/NV for review. A schedule and work plan have not been fully developed. These will be developed in conjunction with Fenix & Scisson and Holmes & Narver after both the shaft construction method and location have been selected.

At the request of DOE/NV, SNL input was provided to the horizon definition meeting for the Exploratory Shaft design (Mercury, June 30, 1982). The thermal and mechanical properties of the Topopah Spring Member were discussed. The tests and core evaluation to date indicate that there is sufficient strength over an acceptable thickness in the Topopah Spring Member to allow construction of the breakout area near the Exploratory Shaft. This statement is based on the assumption that stability can be assumed in areas that have up to 10 percent lithophysae. Further testing of the lithophysae

effects on strength and evaluation of lateral variability will be done as part of the Yucca Mountain Analysis.

1.6.4.3 Test and Evaluation Facility

Objective: To develop and operate an in situ Test and Evaluation Facility in a potential repository unit in tuff to characterize the unit and to predict repository performance.

Activities terminated by DOE/HQ on April 9, 1982.

1.6.5 SUPPORT FACILITIES

1.6.5.1 E-MAD Facility

Objective: To ensure the availability and readiness of the E-MAD Facility to meet programmatic needs, and to maintain and develop the capabilities to meet programmatic requirements.

Project Management, Planning, and Control

All contract deliverables were completed and transmitted to the DOE/NV. These were:

-- Draft final report for Task 5, Planning for a Co-Located Generic Packaging Facility.

-- Updated expenditure plan for the third quarter of FY 1982.

-- Updated annual work plan.

-- Updated training schedule.

-- Updated equipment maintenance schedule.

-- Narrative report of quality assurance second quarter FY 1982 activities.

Meetings, negotiations, and preparation of task identification with schedules and costs resulted in authorization for Westinghouse Electric Corporation--Advanced Energy Systems Division (AESD)-Nevada Operations to perform the Dry Storage Fuel Integrity Demonstration Tests and the documentation of E-MAD spent fuel assembly histories and predictions of peak clad temperatures. The overall E-MAD Facility activity schedule was revised to reflect additional tasks and changes to other activities affected by those additions.

The list of AESD-Nevada Operations procedures was updated and issued. The following documents were published:

WN-DPN-100, Rev. 02, AESD-Nevada Operations Procedure Program

WN-DPN-543, Rev. 01, E-MAD Compound Personnel Control

WN-DPN-811, Nonexempt Employee Time Reporting

WN-FEP-016, Two-Ton Monorail Hoist Maintenance

WN-FEP-023, Crane and Hoist Recertification

WN-FEP-036, Bridge Crane Maintenance

WN-FEP-045, Rev. 02, Maintenance of the Manned Control Car

WN-FEP-051, Rev. 01, Maintenance of the Prime Mover (L-3)

WN-FEP-053, Rev. 01, Maintenance of the 25-Ton Locomotive

WN-FEP-054, Rev. 01, Maintenance of the E-MAD Spacer Car and Flatcars

WN-FEP-055, Rev. 01, Maintenance of the Emplacement Installation Vehicle (EIV)

WN-FEP-056, Maintenance of the Emergency Diesel Generating System

WN-HSP-007, Safety Inspections

WN-HSP-009, Fire Protection

WN-HSP-020, Safe Work Permits

WN-HSP-021, Lock and Tag

WN-HSP-023, Electrical Safety

WN-HSP-024, Flammable Liquids

WN-HSP-025, Cutting, Welding, and Compressed Gas Bottle Handling

WN-P-004, Rev. 02, AESD-Nevada Operations Documentation Plan

WN-TI-015, Calibration of the Autodata Nine, Data Logger System

WN-TOP-012, Rev. 04, Prepare and Ship Climax Fueled Canisters

WN-TOP-020, Rev. 01, Obtain Gas Samples From a Welded Storage Canister

WN-TOP-025, Rev. 02, Canister Cutting Tool

WN-TOP-100, Rev. 05, Generic Guidelines and References

A preliminary evaluation indicates that the E-MAD Facility has in place all of the operational capability to support the DOE Headquarters program to accelerate the development of technologies to store spent fuel.

Efforts to site a Test and Evaluation Facility at the NTS were suspended by DOE on April 9, 1982.

Meetings were attended in Germantown (DOE Project Managers), Denver (DOE Technology Transfer), Richland (Dry Storage Fuel Integrity Demonstration), Pittsburgh (DOE and Sandia/Albuquerque Transportation Technology Center cask test discussions), and Las Vegas (Technical Integration Group, program review of defense low-level waste programs).

Capability Maintenance

Operator Training and Qualification--Operators were requalified to operate:

- Floor-Mounted Handling Systems (FMHS) (4)
- Master-Slave Manipulators (MSM) (2)
- V-202 Remote-Operated Bridge Crane (6)
- Warner-Swasey Mobile Hydraulic Crane (2)
- Railroad Transport Systems (4)
- Forklifts (1)
- Radiation Shield Doors (1)
- Pass-Through Drawers (1)
- Radiation Area Work (26)
- Rad Safe Dressout/Undress Wall-Mounted Periscopes (3)

Classroom and hands-on training included:

- Canister Cutting
- Dry Runs
- Mass Spectrometer Leak Detection
- Forklifts
- Wall-Mounted Periscopes
- Plasma Arc Welder
- Sample Bottle Bake-Out System
- Canister Evacuation System
- Engine Transport System Maintenance Building
- Manned Control Car

Lectures were presented for:

- AESD-Nevada Operations Procedure Familiarization
- Radiation Worker Qualification
- Receiving Area Forms
- Snakes/Snakebite Procedures (Safety)
- Westinghouse Performance Management System
- Radiation Indoctrination
- Understanding Engineering Drawings

Rad Safe Dressout/Undress
Critique on Fuel Handling and Gas Sampling

Dry runs were conducted for canister gas sampling operations.

Equipment Maintenance--Maintenance, upgrade, calibration, and operational checkout of facility systems continued.

-- The air-conditioning system was prepared for summer operation.

-- High-range and very high-range Remote Area Monitor (RAM) units were calibrated.

-- Quarterly maintenance was performed on the Railroad Transport System (RTS) Manned Control Car.

-- The emergency evacuation bus was serviced, checked out, and test driven.

-- A PA/evacuation/take cover alarm panel was installed in the AESD-Nevada Operations manager's office.

-- A sandblasting booth was manufactured to meet OSHA requirements.

-- The canister leak detection system was calibrated.

Two bids were received for refurbishment of the radiation shielding windows which were removed from the R-MAD Facility. The bids were evaluated by Engineering and Quality Assurance.

Support was provided to the Los Alamos National Laboratory (LANL) in retrieval of the LANL shipping cask and shipping it to Los Alamos.

Engineering and Quality Assurance--In addition to work reported in specific tasks later in this report, Engineering activities included:

-- Providing input for plans, schedules, and cost estimates for E-MAD participation in the DOE Dry Storage Fuel Integrity Demonstration.

-- Preparation of various procedures, including revisions of Technical Operations Procedures (TOPs) -012, -020, -025, and -100.

-- Providing input to the E-MAD Master Schedule revision.

-- Preparing work orders for various activities, such as radio installations and changes.

The narrative report on quality assurance second quarter activities was completed and transmitted to DOE.

A quality assurance lead auditor certification examination was prepared as a requirement of ANSI/ASME NQA-1, Quality Assurance Program Requirements for

Nuclear Power Plants. The examination was administered to two members of the AESD-Nevada Operations quality assurance group. Both individuals passed the examination and were certified as lead auditors.

An audit checklist was developed for use in the quality assurance audit to be performed in the area of AESD-Nevada Operations safety.

Efforts are continuing, with the operations group, in assuring that all electronic/electrical/mechanical measuring and test equipment and devices are currently calibrated and that the calibrations are properly documented.

At DOE request, the Quality Assurance Manager reviewed the Quality Assurance Program Plan for DOE-Nevada Defense Low-Level Waste. Comments were transmitted.

Quality assurance surveillance was provided for all preparations and fuel handling operations to acquire canister gas samples.

Evaluation comments were provided on bid proposals for refurbishment of R-MAD shield windows.

Administration--The FY 1982 work plan, expenditure plan, training schedule, and equipment maintenance schedule were updated for the third quarter and submitted to the DOE.

The Health and Safety Policy Committee charter was revised and the revision was approved by the AESD-Nevada Operations Manager.

Twenty-nine (29) E-MAD Facility tours were conducted for approximately 440 people during this reporting period:

Visitors	Number in Group
1. German and Japanese citizens with University of Arizona students	2
2. American Chemical Society group	70
3. LLNL employee with civic group	10
4. New York Times reporter	1
5. USGS group	5
6. Deputy Secretary and Special Assistant to DOE Secretary for Program and Policies and Assistant, Office of Secretary	3
7. DOE/San Francisco and NTSSO employees	2
8. Allied General Nuclear Services employees	2

Visitors		Number in Group
9.	Japanese and German citizens	19
10.	American Society of Civil Engineers	90
11.	West German citizen	1
12.	Acting Under Secretary and Executive Director of Office of Assistant Secretary for Defense Programs	2
13.	Controller and Acting Director of Budget, DOE	2
14.	Indian Springs, Nevada, citizens and PTA members	63
15.	Industrial Forum press group	10
16.	REECo Medical/Las Vegas physicians and wives	37
17.	Atomic Industrial Forum	45
18.	DOE Assistant Manager for Defense and DOE group	11
19.	Vandenberg Air Force personnel	1
20.	Battelle PNL employees	4
21.	DOE/Headquarters employee	1
22.	Director, DOE Manpower Resource Management; Management Analyst for DOE Organization Planning and Management Division; Program Analyst, DOE Defense Programs; Director, Personnel Division, DOE Richland Operations Office	4
23.	EPA off-site monitors	30
24.	Texas Lt. Governor's staff and residents	8
25.	North Pacific Research employees and one citizen of the Republic of South Africa	5
26.	Citizens of Switzerland	2
27.	Senator Howard Cannon and aide	2
28.	Deputy Secretary, DOE, and aide	2
29.	Administrative Assistant/Chief of Staff to the Secretary, DOE, and Staff Assistant to the Secretary	2

Operational Support of Climax Spent Fuel Test

Notice was received that the next fuel assembly exchange, which was scheduled for the week of August 2, 1982, has been postponed two weeks. A letter was transmitted to DOE requesting change of due date for the contract deliverable report of this fuel exchange from August 15 to September 20, 1982.

Cost estimates were prepared for AESD-Nevada Operations participation in the Climax Spent Fuel Test decommissioning activities.

Future Uses of E-MAD Waste Packaging Capability

The final report has been drafted and is in the internal review process.

Planning for a Co-Located Generic Packaging Facility

The draft report of AESD-Nevada Operations assessment of requirements for a Generic Packaging Facility was completed and submitted for review to DOE and ONWI (Office of Nuclear Waste Isolation). No comments have been received to date.

Three basis options were discussed in the report:

-- Overpacking of High-Level Waste (HLW) packages and spent fuel, with fuel disassembly.

-- Overpacking of HLW packages and spent fuel, without fuel disassembly.

-- E-MAD Facility modified for fuel diassembly only.

Eight different packaging alternatives were addressed with typical packaging flow diagrams, facility layouts, equipment and support requirements, and projected staffing requirements.

Planning for Packaging Support of TEF in Tuff

This AESD-Nevada Operations task was authorized by DOE to commence on April 5, 1982. On April 9, 1982, all efforts were suspended by direction received from the DOE.

During the period of activity, preliminary engineering investigations were initiated. Floor plan layouts were prepared for potential use of the Area 410 MAD Building (2204) in disassembling spent fuel assemblies for the TEF. Work breakdown structures were prepared which included quality assurance activities to assure that waste packaging operations would be performed in a manner that would not prohibit future licensing of the facility.

Data Collection

The last available data for stored spent fuel assemblies were acquired on April 28, 1982. On May 3, 1982, the data acquisition system was damaged by lightning. Damaged circuit boards were shipped to the manufacturer for

repairs, which have been completed. Upon receipt and installation of the circuit boards, the system will be recalibrated and returned to service.

During this reporting period, the highest temperatures recorded on the liners and canisters in the ongoing spent fuel storage tests were:

	Highest Canister Temperature	Highest Liner Temperature
Drywell #1, FA B-43	178.0°F (81.12°C)	141.3°F (60.73°C)
Drywell #2, FA B-41	179.4°F (81.90°C)	140.3°F (60.17°C)
Drywell #3, FA B-03	189.4°F (87.45°C)	147.0°F (63.89°C)
Drywell #5, FA D-22	243.5°F (117.51°C)	200.9°F (93.84°C)
SSC #2, FA B-02	139.2°F (59.56°C)	---
Lag Storage Pit, F/A D-06-- highest exhaust temperature with exhaust fans off	75.8°F (24.34°C)	

No additional drywell liner thermocouple failures were reported through April 28; there have been no indications of changes in storage configurations. Therefore, the maximum canister temperatures are projected to be well within the canister design limits.

All drywells were opened during this reporting period to remove fueled canisters for gas sampling. While the drywells were open, it was observed that moisture was collecting in the liners. Drywell 2 contained approximately two to three inches of water. Liner instrumentation could not be removed from any of the liner thermocouple tubes in the drywells.

Damage was incurred to the conduit which carries instrumentation to Drywell 5 during excavation of the conduit trench for the south stack air monitor detector enclosure. The drywell instrumentation conduit, which was separated at a joint, was repaired. Thermocouple checks indicate no damage to the instrumentation; however, final confirmation will be made when repairs and recalibration of the data acquisition system are completed.

RAM/CAM/Stack Monitor Integration

All components for the stack air monitor were received.

Construction of enclosures for the stack air monitor detectors was initiated. Underground conduit is complete except for stub-ups. Grade stakes were set and the subbase filled and compacted. Installation of interior conduits was started.

The stack air monitor vendor is preparing a quotation for providing the necessary interface with the RAM system console which the current design does not provide.

Dry Storage Fuel Integrity Demonstration Tests

Initial activities in this task included preparation of a preliminary schedule for canister gas sampling, fuel/canister contamination survey/inspection, and the Fuel Temperature Test. An investigation was made of the capability of REECo's Environmental Sciences Laboratory in Mercury for analyzing gas samples. A preliminary assessment was made of modifications required to perform the Fuel Temperature Test. The Fuel Temperature Test stand controllers were checked to determine capability to match spent nuclear fuel thermal decay profiles.

Test plans are in preparation for gas sample analysis and canister/fuel assembly contamination inspections.

A filter body and a package of .45-micron filters were obtained from REECo for canister/fuel inspections. An interface is being designed for the filter and the existing gas sampling system.

The first gas sampling operations were performed. Canisters containing fuel assemblies B-03, B-41, B-43, and D-22 were removed from the drywells. Gas samples were acquired and the canisters were returned to their respective drywells. The canister containing fuel assembly D-06 was removed from storage in a hot bay lag storage pit, gas samples were obtained, and the fueled canister was returned to its storage location.

A meeting was held with REECo to resolve logistics and technical issues associated with moving the Surface Storage Cask (SSC) from its pad in the E-MAD Facility compound into the Hot Bay, and its subsequent return to the pad after canister gas samples are obtained. A load test was performed on lift rigging, which will be used for this operation. Load tests of the tractor and trailer and magnetic particle examination of the trailer are scheduled to be performed the first week of July. A work order was issued for the actual SSC move, which is scheduled for the week of July 12, 1982.

E-MAD Spent Fuel Assembly Histories and Predictions of Peak Temperatures

A preliminary task outline and schedule were prepared and distributed for internal review.

A report outline is in preparation.

Summary histories were prepared for the 17 fuel assemblies which include date of fuel assembly receipt at the E-MAD Facility, major processing operations, locations and durations of storage, definition of available temperature data, and periods of testing at Climax (if applicable).

1.7 LAND ACQUISITION

Objective: To protect and acquire land for possible future use as a repository.

(No NNWSI work funded this fiscal year.)

1.8 PROGRAM MANAGEMENT

Objective: To direct and assure coordination of all activities to fulfill the goals and objectives of the Project and to coordinate the Project with the NWTS Program.

1.8.1 PROGRAM MANAGEMENT

Objective: To provide the management interfaces between the participating organizations.

This task has no reportable progress.

1.8.2 PROJECT CONTROL

Objective: To monitor the fiscal and technical accomplishments of the Project.

This task has no reportable progress.

1.8.3 INTERFACE ACTIVITIES

Objective: To implement technical interfaces between NWTS Projects.

This task has no reportable progress.

1.8.4 QUALITY ASSURANCE

Objective: To provide the necessary planned and systematic actions and administrative controls to assure all NNWSI activities which affect quality, safety, reliability, or maintainability are conducted in accordance with established Project requirements.

The first draft of the quality assurance (QA) chapter of the Site Characterization Report (SCR) was completed and placed in the hands of the Sandia SCR coordinator, Jim Neal, Technical Overview, on April 28, 1982. Due to the press of time, it was submitted prior to complete final review and approval by the Quality Assurance Overview Contractor (QA Overview) on the premise proposed by Mr. Neal that QA Overview will have another opportunity later to incorporate any necessary corrections.

In June, QA Overview followed up on SCR development by polling participant organizations to determine whether or not the appropriate QA information is being included. The general concensus was that this is an area for concern; however, progress is being made and assistance from QA Overview is not needed at this time.

QA Overview has begun submitting QA records to the Project Record Center per requirements in the NNWSI Record Management Plan (QMP 17-01). QA Overview records were submitted in April. QA Overview is assisting Technical Overview in preparing their records for forwarding to the Project Record Center.

At the direction of the Project Office, QA Overview checked with the various NNWSI organizations on the status of their submittal of QA records to the Project Record Center. A summary report of this survey was provided to D. L. Vieth on June 17, showing that Westinghouse, H&N, F&S, and QA Overview had sent records to the Project Record Center at the time of the survey. Sandia was in the process of preparing a record package that has since been submitted to the Project Record Center.

To follow up this report, QA Overview visited the Project Record Center in late June to see if there were any problems to be ironed out with H&N. A minor problem with Sandia submittals was resolved. H&N provided a printed set of record submittal instructions which will be incorporated into the NNWSI Record Management Plan. The revised NNWSI Record Management Plan will be completed in July.

QA Overview has been working with Technical Overview to assist them in developing activity plans for their activities as defined in the Management and Overview QA Program Plan (NVO-196-18). Technical Overview has designated the activities to be described by activity plans. Draft plans are being developed and the first activity plan for the data base management system was provided to QA Overview for review. Several suggestions were made and Technical Overview is revising the plan accordingly. It is anticipated that the plan will be approved in the near future.

The QA Officer attended a DOE/NV meeting in early April to participate in discussions on further application of quality assurance to field activities at the NTS. The discussion focused on those QA actions DOE/NV could directly take to further define methods of interface between the QA of the various NNWSI organizations. A first step was development and implementation of a nonconformance reporting procedure for drilling activities. QA Overview was charged with developing a procedure defining the system. QA Overview has completed the draft of this procedure and forwarded it to the Project Office for their consideration in April.

Additional work was done on the procedure for reporting nonconformances during drilling activities. Project Office comments were incorporated into the draft procedure. This text was the subject of a meeting of representatives from the Project Office, NTSSO, and QA Overview on June 29. Some different approaches to administering the nonconformance reporting system were brought out in the meeting. These comments are currently being incorporated into the procedure text.

QA Overview reviewed the QA Program Plan of Seisdata Services, the F&S subcontractor doing the seismic survey work on Yucca Mountain. This review was requested by F&S, and comments were provided to F&S Quality Assurance at the beginning of April.

QA Overview provided an addendum to the report of NNWSI QA program status originally submitted in early April. The addendum was provided in response to a Project Office request for additional information in several areas.

The auditor training course, "The Practice and Process of Auditing," was presented at SNL on May 24, 25, and 26. Personnel from DOE/NV and SNL who are working on the NNWSI successfully completed this training which is a requirement for NNWSI lead auditors. QA Overview conducted an additional session of the auditor training class from June 29 through July 1 at Sandia, Albuquerque. There were ten attendees at this session, including two from DOE. Names of attendees will be added to the qualified lead auditor listing maintained by QA Overview.

The following documents have been submitted to the Project Office for their approval or instructions to QA Overview for further action. These are open items as of the end of the quarter:

-- Tracking System (AIR) Proposal, January 15, 1982.

-- Quality Assurance Actions for Exploratory Drill Holes, February 11, 1982.

Audit Activities

Audit 82-4 was conducted from April 13 through 15 at U.S. Geological Survey offices in Denver, Colorado. The audit report has been completed and forwarded to the Project Office.

QA Overview and the DOE/NV QA Manager met with LLNL QA personnel to review the LLNL corrective actions to Audit 82-1 and resolve some difficulties with LLNL responses to several audit report items. The difficulties were resolved and their corrective action is complete or proceeding as planned. QA Overview can recommend closing Audit 82-1 upon receipt of several agreed-upon documents evidencing completion of corrective action.

QA Overview reviewed Sandia corrective actions to Audit 82-2. Part of Sandia's corrective action is complete. Remaining corrective action involves preparation of several new procedures. QA Overview will recommend closing Audit 82-2 upon receipt of the procedures now being developed.

A written response was received in May from REECo on Audit 82-6 and was evaluated. A meeting was held on June 3 at the REECo Las Vegas offices to discuss our evaluation. The results of the QA Overview evaluation and the meeting with REECo were documented in a report to the Project Office.

The status of FY 1982 Project Office audits is shown in the following table:

Org.	Audit Date	Response Due	Response Date	Remarks
LANL	1/26-29/82	4/28/82	5/21/82	Response received June 30, 1982 by QAOC; not reviewed.
LLNL	12/16-18/81	3/3/82	3/4/82	Responses reviewed; accepted. Awaiting completion of corrective action before closeout.
SNL	12/9-11/81	3/8/82	2/23/82	
USGS	4/13-15/82	6/17/82	6/21/82	Response received June 30, 1982 by QAOC; preliminary review.
WEC	See Remarks			Audit scheduled to start August 23, 1982.
F&S	3/22-25/82	6/1/82	6/27/82	Response received June 26, 1982 by QAOC; reviewed. Met with F&S; results to follow in a report.
H&N	2/26/82	--	--	Audit closed May 14, 1982. No response needed.
REECo	2/22-25/82	5/7/82	5/3/82	Response reviewed. Met with REECo on June 3, 1982. Awaiting completion of corrective action before closeout.

Sandia National Laboratories

An external QA audit was performed at Los Alamos Technical Associates (LATA), Los Alamos, New Mexico, on April 28. The primary findings of the audit team involved organization and auditing, basic requirements 1 and 18 of NQA-1, respectively. A satisfactory response was received from LATA in June 1982 and the audit is now considered closed.

Internal QA audits were performed in May and June 1982 on the QA training and audit functions, respectively.

An internal QA audit is scheduled for the Materials Characterization Department, Organization 1820, for June 30 and July 1. This audit will be chaired by the Inspection/QC Division, Organization 7411, and will include the Organization 9700 QA Chief.

A meeting was held with the NNWSI staff to discuss changes to the peer/design review and document acceptance/approval process in Organization 9700. This meeting was held on April 23, and has since been presented (via video tape) to the remainder of the staff.

The assignment of QA levels to NNWSI SNL tasks was completed in April 1982. Future NNWSI SNL tasks will be assigned QA levels as such tasks are identified.

A quality assurance procedure covering NNWSI QA records administration was developed and revised once during this report period. Actual transfer of records began in June 1982. During this time, the NNWSI Central File at SNL was reorganized to conform to the existing Division File Guides.

The Organization 9700 QA Chief has met with NNWSI QA Overview on several occasions to discuss SNL's response to QA Audit 82-2. The only open matters concern the development of or revision to QA Procedures. Work is under way on these procedures, and they should be completed during the next quarter.

G. R. Romero, 9772, and J. R. Tillerson, 9763, attended the Workshop for Site Characterization QA in Denver, Colorado, on June 29.

Effective June 16, G. R. Romero, 9772, began to function as the NNWSI QA Engineer. He replaced W. A. Hunt who has moved on to other matters at SNL.

Activity Plans and Instructions (APIs) are required for each activity on the WBS as part of the NNWSI Performance Assessment Quality Assurance Program Plan (QAPP). The Activity Plan for Performance Assessment were characterized as being conceptual in nature: identifying the objectives, goals, methods of analysis, and milestones; whereas the Activity Instructions were identified as the set of procedures which shall guide the safegurding and application of computer codes. The need for coordination between the Quality Assurance and Performance Assessments Divisions in developing a set of Activity Instructions was recognized.

The Activity Plan for the Data Base Management System was completed and is in the process of review. Topics for Activity Instructions for operation of the Data Management System have been identified. The Activity Plan inputs for Unit Selection and Code Acquisition and Validation are being assimilated.

U.S. Geological Survey

An audit was conducted by DOE in Denver and at the NTS. Los Alamos QA personnel represented the USGS at all QA audit meetings. Answers prepared in response to the DOE/NV audit findings were sent to the USGS.

Revisions to the Gravity Measurements and Data Reduction Procedure, the Earthquake Location Procedure, and the Methods for Determination of Radioactive Substances in Water Procedure were distributed to holders of the USGS Manual of QA Procedures. A draft of the QA Peer Review Procedure has been prepared. The Instrument Calibration Procedure for Seismic Studies has been established

and sent out for approvals. The QA office reviewed and commented on a Notebook for Quality Assurance for NNWSI work. Comments were presented at a QA-Interface Coordination Group meeting.

A meeting was held with Fenix & Scisson personnel to develop a plan for their participation in the USGS drilling program.

At the Nuclear Regulatory Commission technical sessions held in Las Vegas and at the NTS, QA personnel made a presentation on the USGS QA Program.

Los Alamos National Laboratory

Several meetings were held with technical personnel to gather information for a Technical Review of Publications procedure. A draft of the procedure has been prepared and distributed for comment.

The QA office reviewed a Notebook for Quality Assurance for NNWSI work; comments were presented at a QA-Interface Coordination Group meeting.

QA personnel transmitted their comments on the ES Conceptual Design Report to Los Alamos NNWSI office and NNWSI, and potential repository sites were examined at the NTS. The QA section for the ES Project Management Plan was prepared and given to the Los Alamos NNWSI office.

Procedures and work plans are being revised to be consistent with Los Alamos report format. Some of the procedures recently revised are the QA Program Plan, the Document Control procedure, the Volcanic Hazards Work Plan, the Work Plan for Actinide Chemistry, the Mineralogic and Petrologic Studies Work Plan, and the Siemens X-Ray Diffraction procedure.

An internal audit was performed for procurement activities of the Los Alamos NNWSI work on May 12.

Answers to the DOE-NV/Overview Audit 82-3 were written and distributed.

Lawrence Livermore National Laboratory

Surveillance of NNWSI projects continued this quarter with frequent interactions between the PQE and Waste Package personnel. An effort has also been made to follow the evolution of the Site Characterization Report to assure the inclusion of references to quality plans and requirements, where appropriate.

LLNL/NNWSI projects were the subject of a followup audit. The audit team, John Rinaldi, DOE/NV; John Dronkers, DOE/SAN; and Jerry Rudolfo, QAOC/Sandia, came to LLNL to verify corrective action taken by LLNL to close out Audit 82-1 and discuss outstanding issues. The audit was recommended for closeout, but the action will be suspended until proof of all corrective action is reviewed.

The PQE made a trip to LANL and Sandia, Albuquerque, this quarter to meet with QA personnel and discuss techniques used to implement controls.

The PQE attended the "Reliability Engineering Institute" sponsored by the University of Arizona and Hughes Aircraft. Valuable tools for predicting the probability of failure and the reliability of equipment and systems were discussed.

The PQE met with SFT-C personnel to discuss recommended changes to the Mothballing/Demothballing procedures based on the October 1981 fuel exchange. These changes have been incorporated for the next fuel exchange in August 1982.

A lead auditor system is currently under study by DOE/SAN and LLNL with the intent of providing a uniform approach to certification. Interim certification of lead auditors at LLNL was sent to the PQE by the LLNL QA office and is effective July 1, 1982.

A second draft of the WIP Quality Management Plan (umbrella) was circulated for internal review and comment. In addition, the following procedures were drafted and are under internal review: Nonconformance Correction Procedure, Rev. 2; Procurement Control Procedure; and Procedure for the Technical Review of Publications.

The PQE has met with several WIP project and computer personnel to discuss quality assurance as it relates to computer code documentation. Which codes to include in the QA file is still a matter to be resolved.

Preparation for the transmittal of QA records to the H&N Record Center in Mercury is nearly complete. Records will include those pertaining to the Radionuclide Migration Experiment; the High-Temperature Permeability in Rock project; and plans, procedures, and publications for the Spent Fuel Test--Climax project.

1.8.5. SPECIAL SUPPORT

Objective: To provide special technical support to the NWTS Program.

An appendix describing NNWSI's Performance Assessment Plan and activity was written for the NWTS Performance Assessment Plan.