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QA: N/A
Project No. WM-00011

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OVERNIGHT MAIL

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TRANSMITTAL OF TEST PLANS FOR KEY TECHNICAL ISSUE (KTI) AGREEMENT ITEM UNSATURATED AND SATURATED FLOW UNDER ISOTHERMAL CONDITIONS (USFIC) 4.01

Reference: Ltr, Ziegler to Schlueter, dtd 10/31/03

This letter transmits *Test Plan For: Moisture Monitoring in the Enhanced Characterization of the Repository Block (ECRB) Bulkheaded Cross Drift* (enclosure 1) and *Test Plan For: Niche 5 Seepage Testing* (enclosure 2), as described in KTI Agreement USFIC 4.01. These plans are referenced in Sections C.4.3 and C.4.7 of the *Technical Basis Document No. 3: Water Seeping into Drifts*, which was submitted by the referenced letter, and are being submitted separately.

The KTI Agreement USFIC 4.01 deals with hydrologic testing and analyses conducted at Yucca Mountain, Nevada, by the U.S. Department of Energy (DOE). One part of this agreement specifies that DOE document the test plans for the above tests. These test plans are in the enclosures to this letter, and provide the remaining information to complete KTI Agreement USFIC 4.01.

There are no new regulatory commitments in the body or enclosures to this letter. Please direct any questions concerning this letter and its enclosures to Eric T. Smistad at (702) 794-5073 or Carol L. Hanlon at (702) 794-1324.

OLA&S:TCG-0169

Joseph D. Ziegler, Director
Office of License Application and Strategy

Enclosures:
1. *Test Plan For: Moisture Monitoring in the ECRB Bulkheaded Cross Drift,* SITP-02-UZ-001 Revision 00
2. *Test Plan For: Niche 5 Seepage Testing,* SITP-02-UZ-002 Revision 00

NMSS07

WM-11

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MOL.20011018.0011

Bechtel SAIC Company, LLC

Test Plan For:
Moisture Monitoring in the ECRB Bulkheaded Cross Drift
SITP-02-UZ-001 REV 00
WBS Element 1.2.22.4.U (Work Packages P4D1224UF1 and 8191224UUA)

Prepared by:

9/28/2001
Date

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Enclosure 1

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REVISION/ADDENDUM HISTORY

Revision Number	Addendum/ Addendum Revision Number	Effective Date	Purpose of the Revision or Addendum
00	0	10/18/2001	Initial issue

DISCLAIMER

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1. INTRODUCTION

This test plan SITP-02-UZ-001 was developed per AP-SIII.7Q. As per these requirements, this test plan provides additional detail for the ongoing moisture monitoring portion of unsaturated zone field testing in the Enhanced Characterization of the Repository Block (ECRB) Cross Drift. This test plan SITP-02-UZ-001 describes only work to be done in the bulkheaded section of the ECRB and does not replace other moisture-monitoring studies currently ongoing in the ESF and elsewhere in the ECRB. The study described herein is designed to detect seepage in sealed drift sections and to evaluate the drying effects of ventilation and construction activity on the underground moisture conditions. The last 918 m of the ECRB Cross Drift (from Station 17+63 m to Station 26+81 m) currently has three sections that are separated by bulkheads. The first two sections penetrate the area below the Yucca Mountain ridge, where the potential for seepage may be high due to the high surface net infiltration rates under ambient conditions, especially in the area with only fractured welded tuff above and no non-welded tuff. The second section also intersects the Solitario Canyon fault. The third section encloses the Tunnel Boring Machine (TBM) used for the ECRB Cross Drift excavation.

The data collected between and during periodic bulkhead entries form the basis for this modification of the test design. Liquid water was observed during previous entries to bulkheaded sections. The current focus is to determine the origin of observed liquid water by using improved methods for collecting water samples and quantifying gaseous moisture. Preliminary chemical analyses indicated that the origin of liquid water in the ECRB Cross Drift could be the results of condensation associated with the heat output of the TBM in the last section of the ECRB Cross Drift. Additional measurements to quantify thermal-hydrologic conditions are planned.

2. PRODUCT SUPPORTED

This test plan is covered under Technical Work Plan for Unsaturated (UZ) Flow and Transport Model Report TWP-NBS-HS-000001, Rev. 01 (2001), and the Field Work Package for Moisture Studies In The ESF: FWP-ESF-96-004, Rev. 6 (2001) and supports the Site Recommendation Product (WBS element 1.2.21.3.U) and the License Application Product (WBS element 1.2.22.4.U). While some of the modifications described in this test plan can support the Site Recommendation, much of the data from the new monitoring and sample collection facilities will be available to support Analysis and Modeling Reports (AMRs), the Unsaturated Zone Flow, Transport and Coupled Processes Model Report, engineering design packages, and chapters of the License Application.

3. QUALITY ASSURANCE AND INTEGRATED SAFETY MANAGEMENT SYSTEM PROGRAM

This test will be performed in full compliance with the Yucca Mountain Quality Assurance (QA) and Integrated Safety Management (ISM) requirements. Section 4 of

FWP-ESF-96-004, "Moisture Studies in the ESF" describes various aspects of the Environment, Safety, and Health (ES&H) requirements and compliance. This document also contains a hazard analysis for testing activities.

3.1 APPLICABLE QA PROCEDURES

3.1.1 Test Plan

AP-SIII.7Q Scientific Investigation Laboratory and Field Testing

3.1.2 Test Controls

AP-3.10Q	Analysis and Models
AP-3.11Q	Technical Reports
AP-3.12Q	Calculations
AP-3.14Q	Input Request
AP-5.2Q	Testing Work Packages
AP-SI.1Q	Software Management
AP-SIII.1Q	Scientific Notebooks
AP-SV.1Q	Control of the Electronic Management of Data

All activities in the field will be coordinated with the TCO.

3.1.3 Record Controls

AP-SIII.3Q Submittal and Incorporation of Data to the Technical Data Management System

All records will be submitted to the Record Processing Center in records packages.

3.1.4 Equipment/Instrument Calibration Records

AP-7.6Q	Procurement of Items and Services
AP-7.7Q	Acceptance of Items and Services
AP-12.1Q	Control of Measuring and Test Equipment and Calibration Standards

Calibration services will be procured through BSC from qualified vendors. Calibration records will be submitted with data submittals as part of the records package.

3.1.5 Inspections and Audits

AP-16.1Q Management of Conditions Adverse to Quality.

3.1.6 Nonconformance and Corrective Actions

AP-15.2Q Control of Nonconformances.

4. PURPOSE AND OBJECTIVE

4.1 PURPOSE OF TESTING

The moisture monitoring program collects moisture data in the drifts and surrounding rocks to quantify moisture removed by natural and forced ventilation, drying and rewetting of rocks around the drifts, liquid seepage into drifts, and redistribution of moisture from evaporation and condensation processes.

4.2 APPLICATION OF TEST RESULTS

Data collection and modeling associated with the moisture monitoring effort iteratively improve the understanding of moisture dynamics and help to quantify the uncertainties of moisture evolution. These insights, in turn, provide a better understanding of UZ flow, transport, and coupled processes as well as in-drift moisture-redistribution processes. The site-scale and drift-scale models, together with performance-assessment models, can use the field data to calibrate and validate the models by testing predictions.

5. WORK SCOPE

5.1 PRODUCT DESCRIPTION

This test plan provides additional detail for sealed bulkhead test in the ECRB Cross Drift of the moisture-monitoring portion of field testing covered under the Technical Work Plan for Unsaturated (UZ) Flow and Transport Model Report TWP-NBS-HS-000001, Rev. 01 (2001). This test plan covers a specific portion of the overall work activities. The scope for overall work activity is as follows:

1. Monitor the moisture conditions in the ESF and the Cross-Drift, both in front of and behind sealed bulkheads.
2. Measure water potentials and saturations at selected locations with boreholes.
3. Measure drying front penetration along boreholes normal to the drift wall.
4. Collect relative humidity, temperature, wind speed, and barometric pressure data in drift sections under both ventilated and nonventilated conditions.
5. Monitor rewetting processes and analyze potential seepage under ambient conditions (i.e., without construction activities and thermal perturbations).
6. Measure airflow velocity at selected moisture stations and compare with ventilation data, if available and citable.
7. Evaluate the impacts of excavation, ventilation, and construction-water usage on the surrounding rocks.
8. Submit verified data to technical databases to provide inputs for model calibration and validation.

5.2 RESPONSIBLITIES

The work will be performed by scientists and research associates from the Science and Engineering Testing Department and the UZ Department, Science and Analysis Project, Bechtel SAIC Company, LLC (BSC) and from the USGS.

5.3 ACTIVITIES AND TASK DESCRIPTION

Moisture monitoring in the Cross Drift and in the ESF will be continued to measure the values and distribution of hydrologic conditions and to monitor the re-equilibration of the hydrologic conditions behind the ECRB bulkheads. The existing monitoring study (which is moisture monitoring for the entire ESF and ECRB) includes:

1. Network of heat dissipation probes at approximately 25 m intervals before and behind the bulkheads along the Cross Drift, to measure water potential.
2. Neutron access boreholes at approximately 50 m intervals along the Cross Drift, to allow for measurement of water content during entries to the closed areas.
3. Two thermocouple psychrometer and electrical resistance probe stations behind the bulkheads, to measure rewetting.
4. Moisture and atmospheric measurement stations before and behind bulkheads and in the ESF, to monitor drift relative humidity and temperature conditions.
5. Moisture sensors and canvas sheets in sealed Alcove 7, to monitor rewetting of the Ghost Dance fault (the eastern boundary of the primary potential repository block).
6. Analysis for major, minor and isotopic composition of water samples obtained from puddled areas.
7. Analysis of data, including simulation of hydrologic processes, to determine the effect of construction water usage on surrounding rocks. (Construction-water usage data to be provided by the Determination-of-Importance Evaluation group).

Remote video camera monitoring behind bulkheads will also be implemented, if judged to be feasible, to observe drips and conditions without opening bulkheads.

Previous observations have shown essentially 100% humidity in the bulkheaded sections, and measurement of evaporation in the bulkheaded sections would confound other measurements by contributing additional water to the system. For these reasons evaporation will not be measured. If necessary, corrections for evaporation will be made during data analysis.

Recent observations and evaluations in the ECRB Cross Drift bulkhead study indicated that further modifications to testing could be developed. Potential test improvements along the sealed sections, as illustrated in Figure 1, will focus on the following, to attempt to obtain seepage information and quantify in-drift conditions:

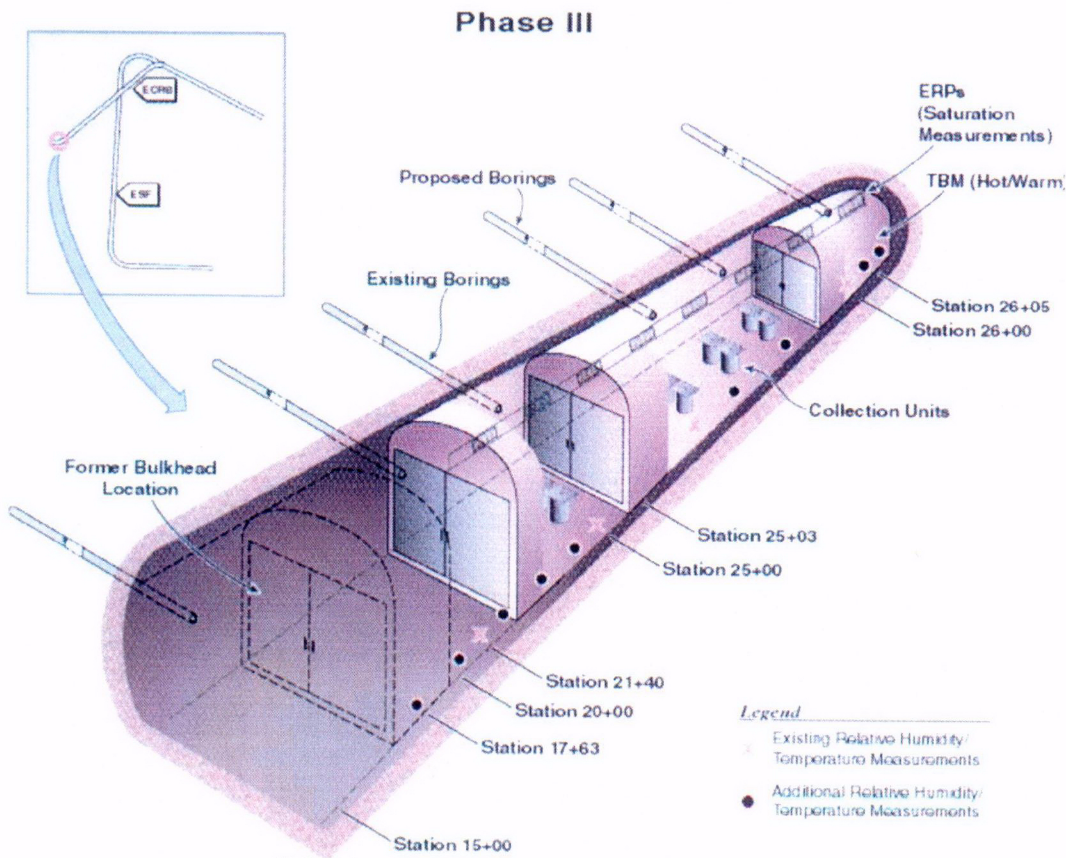

Figure 1. Sensor locations planned for installation into ECRB Cross Drift (schematic not to scale).

C01

1. Move first bulkhead from 17+63 m to 24+00 m (or another more appropriate location depending on field observations during the entry)
2. Identify locations likely to drip and install additional water collection systems, designed to minimize evaporation and avoid liquid contact with rock debris, as illustrated in Figure 2 (4 - 6 collectors planned). Move collectors to correct locations if dripping is observed to occur elsewhere than anticipated.
3. Collect and analyze moisture that drips to determine its origins (i.e., pore water or construction water, condensation, etc., by associated laboratory chemical and isotopic analyses).
4. Investigate feasibility of real-time moisture detection with cameras, and implement if feasible.
5. Install wetting-front, temperature, and moisture sensors along the drift wall (see Figure 1, one 200 - 300 m string planned).
6. Install gas withdrawal and injection ports along the drifts for periodic sampling and tracer-release studies (5 ports planned).
7. Drill additional 5 m boreholes for potential and temperature gradient measurements in sealed sections (4 boreholes planned).
8. Improve spatial resolution of relative humidity, barometric pressure, and velocity distributions by additional moisture sensors along the sections and at selected vertical cross sections, including temperature sensors on the bulkheads.

The original ECRB test to investigate ambient seepage is located in the planned Crest Alcove (planned to be constructed in the out years consistent with current baseline). This test bed would be similar to the bulkhead experiment in the ECRB, but in an alcove off the left rib, away from the heat sources. This test has been in the plan since the original ECRB planning in 1997.

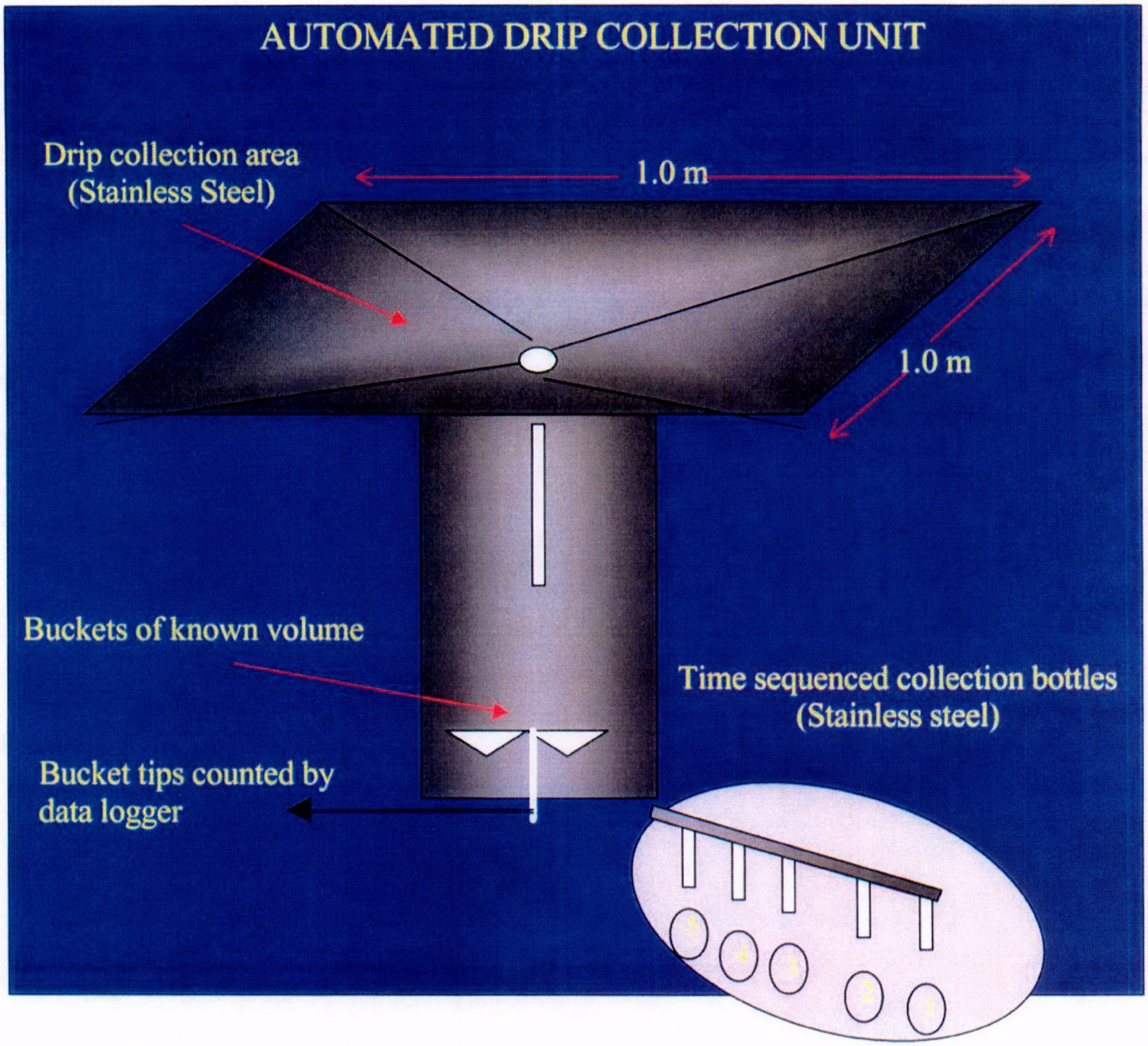

Figure 2. Water collection system for deployment in sealed ECRB sections.

C02

5.4 SCHEDULE

The next bulkhead entry is currently scheduled for October 2001, with the first bulkhead moved closer to the second bulkhead. The move allows the Project to concentrate on the sections where observation of natural seepage, if any, is most likely and improve resolution in the vicinity of the TBM heat source inducing nonisothermal redistribution of moisture.

The remainder of the test with the new test bed configuration (as described in this test plan section 5.3) will last 18 months (October 2001 to April 2003). Start dates for individual activities cannot be provided at this time but will be provided in FY 2002 baseline multiyear project schedule. The sequence of activities consistent with the preliminary draft of the revised YMP baseline would be as follows:

1. Continue planned entries approximately every 6 months (October 2001, April 2002, October 2002, April 2003).
2. Improve future instrumentation to better detect and possibly sample drips.
3. Continue moisture monitoring in ventilated and non-ventilated areas.
4. Continue modeling of the test using improved UZ and EBS process models in parallel with ongoing analyses and documentation, using currently available observations.
5. After enhanced measurements are retrieved from new instrumentation, repeat modeling, using existing process-model codes to yield a better understanding of the test results.
6. Model the test using modified or new codes developed specifically for use in TSPA-LA. These modeling efforts may include code modifications being considered to address issues raised in TSPA-SR and should yield a better understanding of test results by LA.
7. Begin construction of the Cross Drift Thermal Test (Alcove 10), which is located before the first bulkhead and would allow the bulkhead testing to continue uninterrupted.
8. The bulkhead experiment can continue until other testbeds are needed in the reach now controlled by bulkheads. The planned testbeds that would impact the bulkhead experiment are as follows:
   - The first bulkhead would need to be removed to focus the ongoing test and provide space for geotechnical investigations and the Crest Alcove.
   - The second and third bulkheads would need to be removed just before the Solitario Canyon Alcove is to be excavated.

6. SCIENTIFIC APPROACH/ TECHNICAL METHODS

6.1 PRE-TEST CALCULATION / ANALYSIS / MODEL PREDICTIONS

Initial modeling studies of the bulkhead experiment were carried out in 1996 and 1997 to evaluate changes in moisture conditions in the rock surrounding the drift. The rate and extent of rock dryout during the ventilation period and rewetting after installation of the bulkhead were evaluated using the site-scale UZ flow model. In the calculations for dryout, the extent of drying was found to be less than 10 m within 100 years (Ahlers et al. 1996). For the rewetting period after installation of the bulkhead, the models predicted that the fractures would resaturate within 6 months for the reference case, whereas the matrix would require more than 6 years to completely resaturate (Bodvarsson et al. 1997).

The probability of seepage in the bulkheaded section of the ECRB was evaluated in FY2000 using the TSPA seepage-model abstraction. This study assumed that the ECRB had returned to undisturbed moisture conditions in the rock for present-day climate. The seepage results were reported by Stefan Finsterle at the UZ PMR Interactive Review meeting (January 10, 2000). The seepage modeling exercise predicted that there is a 50% chance that one or more seeps will occur in the bulkheaded section of the ECRB. Additional seeps are predicted at lower levels of probability; for example, there is a 10% chance to see four or more seeps between ECRB Station 20+00 m and 22+00 m or two or more seeps between ECRB Station 24+00 m and 25+00 m.

These previous predictions should now be repeated with updated parameters derived from other UZ flow and transport tests in the ESF and in the ECRB Cross Drift. The model results will be used to determine if the origin of the water can be ascertained and if the ECRB Cross Drift can be opened for other tests.

Evolution of the Tests

The monitoring effort behind the bulkheads is an integrated part of the field seepage testing and moisture monitoring program that began with Niches 1, 2, and 4 in the ESF and continues with Alcove 1, Alcove 3/Alcove 4, Alcove 7, Niche 5, and Alcove 8/Niche 3. The seepage studies, together with hydrological measurements in boreholes and benches, provide field measurements and data to be used for calibration and validation of UZ models related to flow and seepage.

Past observations and modeling have shown that, in an open tunnel, the drying effects of ventilation are much greater than any expected seepage. Observations in the open portions of the tunnel clearly show that ventilation is drying the tunnel. To observe potential seepage, the first two bulkheads were installed in the ECRB Cross Drift in June 1999 (see Table 1 for locations). The 918 m long section of drift extends though the Topopah Spring lower lithophysal (Tptpll) and the lower nonlithophysal (Tptpln) tuff units, and includes the Solitario Canyon fault (the western boundary of the primary potential repository block). Table 2 shows the stations where the rock unit contacts were mapped.

Table 1. - Bulkhead Locations

Bulkhead number	Station within ECRB
#1	17+63
#2	25+03
#3	25+99

Table 2. - Rock Unit Contacts intersected by Bulkheaded Sections (All within the Topopah Spring Tuff)

Station	Mapped Contact
23+26	Tptpll / Tptpln (Topopah Spring Tuff lower lithophysal / lower non-lithophysal contact)
25+84	Tptpln / Tptpul (Topopah Spring Tuff lower non-lithophysal / upper lithophysal Solitario Canyon Fault Zone)
26+64	Tptpul / Tptprl (Topopah Spring Tuff upper lithophysal / crystal rich lithophysal Solitario Canyon Fault Zone)

General conclusions from the UZ site-scale flow and transport model suggest that, if seepage were to occur into drifts, it would most likely be in the western portion of the block where geologic conditions are most conducive to infiltration, percolation, and seepage. The characteristics in this portion of the tunnel that make it suitable for such a test is the absence of overlying PTn past about 23+50 and the relatively high percolation rates caused by high infiltration from shallow soils and higher elevation at the surface.

Following observation of condensed moisture on the vent line, cables, and pipes along closed sections of the Cross Drift during the first entry (January 12-13, 2000), additional analysis and planning were conducted to evaluate possible sources of the observed moisture. Part of the analysis focused on the TBM and tunnel lighting as heat sources. It was decided the TBM could not be powered down without the potential loss of a capital asset and would restrict future restarting of the TBM for additional studies. This prompted planning for a third bulkhead to reduce heat transfer near the Solitario Canyon fault. The lighting could be disconnected without safety or maintenance concerns, so those electrical modifications were also planned.

In July 2000, to ameliorate (but not eliminate) the influence of heat sources on the tunnel conditions, a third bulkhead was installed to further reduce heat flow from the TBM (see Table 1). The lights were turned off. These modifications had some positive impact but did not eliminate the effects. To assist in determining the location of drips, drip detection sheets were installed. Recent observations indicate that these were overwhelmed by condensation. Low-wind-speed sensor and surface thermocouples were also installed in July 2000.

6.1.2 Observations–January 22–25, 2001 and May 22, 2001

The first bulkhead was opened at noon on January 22, 2001. The Cross Drift was dry from the first bulkhead (17+63) to about 19+00 m. Photographs from the initial entry show evidence of condensation on the metallic surfaces of the vent line, utility lines, and conveyor belt. Most of the glistening on metallic surfaces that was evident in the initial photographs evaporated rapidly. There was some evidence of rust on metallic surfaces, indicating prolonged presence of water.

Canvas sheets located between 24+75 m to 24+95 m were mottled blue, and drip marks covered the entire sheets. Most of the water was observed in the middle non-ventilated section between the second and third bulkheads from 25+03 m to 25+99 m. This section crosses a major splay of the Solitario Canyon fault at 25+84 m, and there is no overlying nonwelded tuff

(PTn) before this point. All drip detection sheets hung between the second and third bulkheads were wet, with some areas noticeably wetter. Rock debris had fallen onto many areas of the drip sheets. Water was collected from puddles on the conveyer belt. This water was dark, indicating mixture with unknown debris on the conveyer belts. Drier conditions were observed near the third bulkhead. The back. nonventilated section behind the third bulkhead to the terminal end of the Cross Drift (25+99 m to 26+81 m) was dry.

On April 6, 2001 power was cut off to the TBM during routine maintenance of the tunnel electrical system. When maintenance was completed, power to the TBM and to the dataloggers behind the second and third bulkheads was not restored. The temperatures began falling behind the second and third bulkheads and the temperature gradient toward the end of the Cross Drift diminished. During the weeks following the power loss, the battery power to the dataloggers decreased.

To avoid loss of data, another entry behind the bulkheads was made on May 22, 2001 to restore power to the dataloggers and to the TBM. The first bulkhead (at 17+63 m) was opened at 11:10 am. No ventilation was established and entry was permitted at 11:20 am. There was moisture glistening on the utility and vent lines in the first 250 m. The tunnel walls also appeared to be wet but moisture did not appear to have penetrated below the surface. Within two hours the moisture on the tunnel walls and utility and vent lines had evaporated. At 21+00 m everything was dry. Drip marks were again seen on the utility and vent lines about 23+50 m. There were rust spots on the steel channels and on the tracks. There were small drip marks at about a one-meter interval on the conveyor belt, but the water had not accumulated into puddles. A canvas sheet that had been hung on January 25, 2001 at 24+10 m was mottled blue with drip marks covering the entire sheets. The sheets between 24+75 m and 24+95 m were moist and there were drip marks on the utility and vent lines and on the second bulkhead. The second bulkhead was opened at 12:06 p.m. Between the second and third bulkhead the canvas sheets were moist but there was much less puddled water than during the January 22-25, 2001 entry. Everything was moist but there were not many obvious drip marks. There were some small rocks on the conveyor belt. The third bulkhead was opened at 12:17 p.m. There were drip marks on utility lines and instruments cables in the first 10 m behind the third bulkhead. Beyond this point, everything was dry.

Less moisture was observed in the second bulkheaded section during the May 22, 2001 entry than had been observed previously (January 22-25, 2001). No dripping was observed and moisture had not accumulated into puddles, as had been observed previously. Conversely, drip marks were observed in the first 10 m the third bulkheaded section (25+99 to 26+09) during the May 22 entry, whereas this entire section had been dry during the previous entry. These observations indicate that as the temperature gradient decreases, observable moisture tends to move toward the TBM.

6.1.3 Evaluation of Recent Results

We believe condensation is caused by warmer, moist air moving away from the TBM heat source into cooler sections; the moisture source is vapor derived from the rock in the vicinity of the tunnel. Other alternative explanations for the condensation include cool air moving down the Solitario Canyon fault or seepage locally increasing relative humidity. Without eliminating the heat source, the cause of the observed condensation cannot be identified definitively. Moisture conditions are continuously monitored in each of the three nonventilated sections to determine if local thermally induced effects and far-field infiltration effects can be decoupled.

Temperature and relative humidity data from the three nonventilated sections show that the temperature ranged between 25 and 32°C and the relative humidity ranged from about 85% to close to saturation. Barometric pressure was the same throughout the Cross Drift. These changes will be compared to surface variations in barometric pressure and variations in barometric pressure in the Cross Drift ventilated section. The low-velocity-wind-speed sensors indicate a slight increase in air movement in the afternoon. Neutron log data and heat dissipation probe data show continued rewetting after the bulkheads were constructed.

Preliminary results for the chemistry of the water sampled during one entry indicate that most of the samples are contaminated by various sources (including rubber on the conveyor belt, rust, mold, construction-related materials) and therefore cannot be used to determine if the water is condensate or seeping pore water. However, three samples taken from buckets (that have much less contamination than the others) are especially low in chloride and silica contents, which strongly suggests that this water is condensate.

6.2 TEST METHODOLOGY

Field testing and associated modeling is the basic approach for gaining knowledge and understanding of the UZ and drift system and for quantifying uncertainties of future predictions. Pretest modeling and previous data analyses form the basis of test improvement and modification.

6.2.1 Technical Methods

Technical methods vary according to the pertinent physical quantities to be measured and the properties to be derived. Some general requirements are summarized below, with specific requirements recorded in detail in scientific notebooks (SNs), technical implementing procedures (TIPs), technical work plans (TWPs), and field work packages (FWPs).
The SNs include:

- SN-LBNL-SCI-173-V1 (YMP-LBNL-JSW-RS-3): Water Potential Measurements in the ECRB.
- SN-LBNL-SCI-209-V1 (YMP-LBNL-JSW-7): UZ Field Investigations ESF/ECRB
- SN-LBNL-SCI-182-V1 (YMP-LBNL-JSW-RS-5): Moisture Monitoring in the ESF

- SN-USGS-SCI-128-V1: Moisture Monitoring in the ESF and Cross Drift
- SN-USGS-SCI-129-V1: Moisture Monitoring in the ESF and Cross Drift

The TIPs include:

- YMP-LBNL-TIP/AFT-1.0 Rev. 1: Balance Calibration
- YMP-LBNL-TIP/AFT-6.0 Rev. 2: Psychrometer Measurements
- YMP-LBNL-TIP/AFT-8.0 Rev. 1: Use of Electrodes to Determine pH and Ion Concentrations in Solutions
- YMP- LBNL-TIP/AFT-11.0 Rev. 0: Use of ICP-AES or ICP-MS to Determine Aqueous Constituent Concentrations

- YMP- LBNL-TIP/AFT-12.0 Rev. 0: Use of Ion Chromatography to Determine Aqueous Constituent Concentrations
- YMP- LBNL-TIP/TT-9.0 Rev. 0: Hydrogen Isotope Analyses of Waters
- YMP- LBNL-TIP/TT-10.0 Rev. 0: Analysis of the Oxygen Isotopic Composition of Water Samples using ISOPREP 18
- YMP-USGS-HP-14, Rev. 2, Mod. 2: Method for Calibrating Peltier-type Thermocouple Psychrometers for Measuring Water Potential of Partially Saturated Media
- NWM-USGS-62, Rev. 6 Mod. 1: Method for Measuring Sub-Surface Moisture Content Using a Neutron Moisture Meter
- YMP-USGS-HP-97, Rev. 2, Mod. 1: Measurement of Temperature and Relative Humidity Using a Temperature and Relative Humidity Probe
- YMP-USGS-HP-138, Rev. 1: Method for Calibrating Pressure Transducers for Measuring Absolute Pneumatic Pressures in Unsaturated Zone Boreholes
- YMP-USGS-HP-162, Rev.1, Mod. 1: Method for Calibrating Thermistors for Measuring Absolute Temperature in Unsaturated Boreholes.
- YMP-USGS-HP-189, Rev. 1: Method for an Operational Check of the Performance Status of a Standard Platinum Resistance Thermometer
- YMP-USGS-HP-270, Rev. 3, Mod. 3: Electronic Diagnostic Testing Procedure for Calibration and Instrumentation DAS racks, Unsaturated Zone, Borehole Instrumentation and Monitoring Program
- YMP-USGS-HP-288, Rev. 0: Calibration Procedure for Thunder Scientific Series 9000 Automated Two-pressure Humidity Generator

The governing TWP for Moisture Monitoring is:

- TWP-NBS-HS-000001 Rev 01: TWP for UZ Flow and Transport PMR

The FWPs include:

- FWP-ESF-96-004 Rev. 6: Moisture Studies in the ESF
- FWP-ESF-96-001 Rev. 3: Field Test Data Collection System.

6.2.2 Measurement Requirements

Measurement requirements depend on the state of the art for sensor technology. While temperature and pressure sensors are fairly accurate and stable, relative humidity above 90%, potential values near saturation, and velocity measurements in sealed space with

low values are subject to large errors. Standard sensors, together with scientific approaches using new sensors and equipment fabricated for potential applications, are used in the moisture monitoring program.

6.2.3 Accuracy Requirements

For standard sensors, manufacturer-recommended accuracies are generally used as calibration requirements. High accuracy in field deployment is not easily achieved if practically uncontrollable conditions exist. Rugged sensors with relatively low resolution are frequently chosen over delicate sensors. Standard hydrologic practices are used to infer properties from measured quantities. A rough criterion to estimate a parameter within 10% over the range of variability is specified as a general, overall guide to the quantification of accuracy needed for the moisture monitoring estimates. Refined criteria can be specified for specific parameters, as documented in appropriate scientific notebooks, TIPs, TWP, and FWPs.

6.2.4 Test Instrumentation

6.2.4.1 Temperature Monitoring

At moisture stations with

- Vaisala Humid/Temp Probe HMP233A, HMP45C, or HMP35C
- Omega Fine Wire Thermocouples, Type E, Chromium/Constantan
- Yellow Springs Thermistors model 46033.

6.2.4.2 Relative Humidity, Potential, and Wetting Front Monitoring

At moisture stations with

- Vaisala Humid/Temp Probe HMP233A, HMP45C, or HMP35C
- J.R.D. Merrill thermocouple psychrometers.

Along drift walls with

- electrical resistivity probes.

In boreholes with

- psychrometers
- heat dissipation probes.

6.2.4.3 Power Control System

To be measured in the electrical circuit to the TBM.

6.2.4.4 Air Flow Quantity Monitoring

At moisture stations with

- TSI Alnor air velocity transducers, or
- TSI Model 8475 air velocity transducer.

6.2.4.5 Barometric Pressure

At moisture stations with

- Vaisala Analog Barometer Model PTB100A, PTB100B, or PTB101B
- Druck Pressure Transducer PDCR 930/U.

6.2.5 Data Repeatability

Duplicated measurements at several moisture stations will be included at selected locations.

6.2.6 Test Design

6.2.6.1 Design Features

6.2.6.1.1 Test Hardware

Sensors at moisture monitoring stations, along drift walls, and in boreholes.

6.2.6.1.2 Test Assembly

Sensors connected to data loggers.

6.2.6.1.3 Peripheral Test Hardware

Data loggers Campbell CR-7s and CR-10s.

6.2.6.1.4 Test Support Facility Requirements

Craft support for installation. Power reading, ventilation control, and construction water usage from the ESF Constructor. Interfaces with craft and ESF Constructor coordinated by the TCO.

6.2.6.1.5 Power

For TBM maintenance by ESF Constructor.

6.2.6.1.6 Water

Not required for passive moisture monitoring. Seepage and condensate collections on pre-fabricated assemblies.

6.2.6.1.7 Electrical

Stable and continuous electrical power needed to charge data logger and sensor batteries.

6.2.6.1.8 Craft

Needed for reentry support, ventilation control.

6.2.6.1.9 Test Construction Interface

Coordinated by the TCO

6.3 IDENTIFICATION OF COMPUTER SOFTWARE

The software to be used for pre-test predictions includes TOUGH2 v.1.4, ITOUGH2 v.4.0 and similar codes.

Software that is used to control the data aquisition is referenced in the *Field Work Package for Moisture Studies in the ESF* (Mitchell, A. 2001) and in the *Technical Work Plan for Unsaturated (UZ) Flow and Transport Model Report* (Persoff, 2001).

Additional analytical, reporting, presentation or modeling software is currently undergoing development or configuration control and will be captured in scientific notebooks maintained for this test. In addition, software used in the AMRs supported by these results will be reported in those AMRs when developed.

6.4 DATA RECORDING AND DATA REDUCTION

6.4.1 Data Collection System

Data loggers downloaded periodically by TCO in accordance with FWP-ESF-96-001, Rev. 3.

6.4.2 Data Application

Inputs to UZ flow, transport and coupled process models and in-drift ventilation models.

6.4.3 Data Distribution

Through periodic data submittals to the TDMS.

6.5 ANALYSIS AND MODELING DURING AND AFTER TEST

The data acquired from the test will be evaluated to detect out of range conditions and to determine if the test is exhibiting ambient conditions that differ from those previously observed. Periodic updates designed to be included in the appropriate AMRs will be prepared describing status of the test and reporting results. Upon the completion of the test, the data will be analyzed and reported in the AMR listed in section 6.6.

6.6 METHODS TO RECORD DATA AND RESULTS

Moisture monitoring data, analysis results, and test interpretations will be reported in revisions of the Analysis/Model Report *In Situ* Field Testing of Processes, U0015, ANL-NBS-HS-000005 and in AMRs and PMRs associated with UZ flow, transport, coupled processes, and EBS in-drift processes.

6.7 ACCURACY AND PRECISION

To ensure that the collected data meets the project needs, the instruments will be calibrated in accordance with applicable procedures. The instruments for this test either will be calibrated by BN Calibration Laboratory or are procured from vendors qualified by the Project for this purpose.

6.7.1 Experimental/Sampling Artifacts

6.7.1.1 Control/Determination of Independent Conditional Variables

This test is passive and was principally designed originally as observations to empirically evaluate whether or not drips would form under ambient conditions when active ventilation was discontinued as predicted by analytical models. The main method of data collection was visual observation by project scientists during periodic entries and recorded in scientific notebooks. This test was to be similar to other sealed bulkhead investigations already underway or completed in Alcoves and Niches in the ESF. Some instrumentation was already in place as part of the moisture monitoring of the ECRB and was reworked to allow for remote monitoring after the bulkheads were installed. This test plan extends and enhances existing instrumentation based on past observations and analysis conducted by project scientists after previous entries and observations. The independent conditional variables for this test are detailed in Test Instrumentation section (6.2.4) under Test Methodology.

6.7.1.2 Control/Determination of the Boundary Conditions

A series of three bulkheads were installed in the ECRB to seal the rear portions of the tunnel from the effects of active ventilation. Table 1 shows the current locations of the bulkheads. The first bulkhead is scheduled to be moved at part of this test plan. The exact location of the new construction will not be beyond station 24+00 another (lower numbered) more appropriate location depending on field observations during the entry.

6.7.2 Instrument Calibration and Instrument Error

6.7.2.1 Instrument Calibration

The expected measurement accuracy based on manufacturer specifications, calibration procedures of qualified vendors, or TIPs are:

- Temperature with Vaisala Humid/Temp Probe HMP233A: ± 0.2°C (+ 0.005 per °C from 20 °C), Bechtel Nevada Calibration Procedure MAN VA002 Rev 0.
- Temperature with Vaisala Humidity/Temp Probes HMP35C and HMP45C: ± 1°C, Bechtel Nevada Calibration Procedure E0260240 WICAL0017 Rev 0.
- Temperature with Omega fine wire thermocouples, Type E, Chromium/Constantan: ± 1.7°C.
- Temperature with Yellow Springs Thermistors: ± 0.005°C, YMP-USGS-HP-162.
- Relative humidity with Vaisala Humid/Temp Probe HMP233A: ± 2%, 10 to 90%, Bechtel Nevada Calibration Procedure MAN VA002 Rev 0.
- Relative Humidity with Vaisala Humidity/Temp Probes HMP35C and HMP45C: ± 5%, Bechtel Nevada Calibration Procedure E0260240 WICAL0017 Rev 0.
- Barometric Pressure with Vaisala Pressure Transducer PTB100A or PTB100B: ± 0.3 mbar, Bechtel Nevada Calibration Procedure CI-151 Rev 0.
- Barometric Pressure with Vaisala Analog Barometer PTB101B: ± 0.5 mbar, Bechtel Nevada Calibration Procedure E0B12020 WICAL0017 Rev 0.
- Druck pressure transducers PDCR 930/U: ± 0.35 mbar, YMP-USGS-HP-138.
- Water Potential with Westor Peltier psychrometer: ± 0.5 bar, YMP-LBNL-TIP/AFT-6.0 Rev 2.
- Water Potentials with J.R.D. Merrill thermocouple psychrometers: ± 2 bar, YMP-USGS-HP-14.
- Air velocity with TSI Alnor air-velocity transducer: ± 2%, 0.125 - 50 m/s, Procedure to be identified or developed.
- Air Velocity with TSI model 8475 air velocity transducer: ± 3 %, 0.05 m/s to 2.5 m/s, Procedure to be identified or developed.

6.7.2.2 Instrument Error

With the exception of the qualitative observations of conditions during manned entry that are entered into scientific notebooks, all other data will be acquired by the automatic DCS. Instrument related errors could occur only if the conversion factors electronic readouts (voltage, amps, etc.) are inaccurate or the calibration factors are input incorrectly. All efforts will be made during the installation of the test that the data is recorded properly and accurately. In the instance of the pilot testing of the viability of video cameras in observing drips or condensation during closed bulkhead phases, some images may be recorded on videotape equipment or viewed via the Internet connection.

6.7.3 Handling Unexpected Results/Conditions

6.7.3.1 Unexpected Results

In the event that the collected data differ substantially from the pre-test calculations, the modeling assumptions and conditions may require re-evaluation. The differences in the results will be discussed with test team and the analysts to determine why the results are substantially different than those predicted. This may result in model modifications and will be an iterative process. The instrument calibration and unit conversion factors will also be verified.to ascertain if the conversion factors or the calibration methodology is flawed. If necessary, the test may be re-planned (as has been done from the original sealed bulkhead observational test up to the instrumentation program covered by this modification).

6.7.3.2 Unexpected Conditions

Most likely unexpected conditions are:

- out of range readings from the data collection system
- extended power failure
- significant leakage of air through the bulkheads

Unless such conditions persist, the test will be allowed to run and data gathered at a set frequency. Alarms have been incorporated in the data acquisition system to alert the test attendant whenever the test conditions are outside the predicted operating window. Unexpected condition will be evaluated to determine its potential impact on the test to acquire the needed data and to determine whether the test be modified or terminated.

6.7.4 Approach for Test Results

As mentioned in section 4.2, data collection and modeling associated with the moisture monitoring effort will iteratively improve the understanding of moisture dynamics and help to quantify the uncertainties of moisture evolution. These insights, in turn, provide a better understanding of UZ flow, transport, and coupled processes as well as in-drift moisture-redistribution processes. The site-scale and drift-scale models, together with performance-assessment models, can use the field data to calibrate and validate the models by testing predictions. If unexpected conditions or results are gotten, modelers will review the results and develop an impact analysis to determine if the models need to be modified to match the new results. In many cases, the predictive models were developed with built in conservatisms and quantified uncertainties that allow for deviations in actual results without requiring changes in models that would make them less conservative for their intended purpose in long term performance assessment.

7. INTERFACE CONTROL

7.1 PERFORMANCE ASSESSMENT

Total System Performance Assessment models and associated process models at the mountain and drift scales estimate and predict potential drying effects, duration of rewetting under sealed bulkhead conditions, and seepage occurrence along the drifts, as documented in Section 6.1. With heat sources better quantified, in-drift processes can also be predicted. The processes of model prediction, calibration, and validation can improve the confidence and credibility of models used for performance assessments.

7.2 DESIGN

Construction and operational data, such as ventilation rates, construction water usage, and power consumption by the TBM, can be used to quantify external perturbations to the drift and the UZ environment. Designers may chose to utilize results from this test directly or depend upon calculations, AMRs, or the PMR developed to support the Engineered Barrier System (EBS) Process Models.

7.3 PROCESS MODELS

Data obtained from the test are to be evaluated in the AMRs planned for License Application (LA). Modeling of the ECRB bulkhead experiment is critical to the overall investigation as it will help in the interpretation of field observations and provide input for the UZ drift-scale seepage model and EBS in-drift models. A number of new factors important for modeling ECRB moisture response need to be addressed in future modeling studies. These factors are as follows:

1. The active fracture model, which treats fracture-matrix interaction, was not available for the early (1996 and 1997) modeling studies. This is now the standard approach used for modeling fracture-matrix interaction in the UZ flow model.
2. Hydrogeologic properties used in the current UZ flow model have changed since the 1996–1997 model because of the incorporation of new field data and use of the active fracture model.
3. Seepage was predicted using the TSPA model, which includes a number of conservative factors. Some of these conservatisms are being re-examined through the current investigation of unquantified uncertainties.
4. The effects of temperature resulting from operational factors (e.g., lighting and TBM maintenance) now appear to be an important aspect of ECRB moisture conditions. All of the previous modeling studies assumed isothermal conditions.

To address these issues, additional modeling of the UZ and EBS will be performed. The steps for the UZ to be carried out are the following:

1. Calculate rock dryout, using the present UZ flow model incorporating the drift-scale property set and available information on drift environmental conditions during the ventilation period.

2. Calculate rock rewetting, using the present UZ flow model incorporating the updated drift-scale property sets, available information on heat generated by operational factors, and available information on air movement in (and potentially across) the bulkheaded sections.
3. Calculate seepage into sealed drift sections, using process-level seepage models, including the expected rock moisture conditions and the effects of heat associated with the TBM at the terminal end of the Cross Drift.

The steps for the EBS in-drift models to be carried out are as follows:

1. Perform blind calculations of temperature and relative humidity using the present in-drift thermal hydrology model incorporating ECRB bulkhead geometry and rock properties.
2. Once commercial computational fluid dynamics (CFD) codes (currently being used to perform pre-test predictions for the scaled natural convection and ventilation experiments at the Atlas facility) are calibrated and possibly validated by the Atlas tests, they would be tested against the ECRB bulkhead conditions to evaluate process understanding and uncertainty. Results would then be compared against the current in-drift process model and UZ flow and transport model results.

7.4 PARAMETERS

The in-situ parameters that will be collected are detailed in the Test Instrumentation section (6.2.4) under Test Methodology. In general, the parameters that will be measured and evaluated in-situ include temperature, relative humidity, water potential, air flow, barometric pressure. If drips or condensate can be collected by the sampling apparatus, a determination of volume will be taken. Collected water samples will be evaluated in the laboratory for chemical signature as an aid to distinguishing between condensation and seepage from the rock. Key indicators that would be useful for that evaluation would include silica and carbonate content. Other major, minor and trace elements may be measured depending on quantities available.

8.0 MANDATORY HOLD POINTS

No mandatory hold points have been identified for the implementation of this test.

9.0 SECURITY

Test facility and data security is provided by the DOE/NV Safeguard and Security Division (SSD), YMP/BSC Security Department, and direct security support provided by Wackenhut Services (WSI). All work performed in the EBS test facility will be performed in compliance with DOE, YMP/BSC, and WSI security orders/directives.

On-site direct access to the test bed is controlled by the ESF Portal Guard Station inspecting General Underground Training (GUT) card for entries to the ESF and ECRB test facility. Periodic bulkhead entries are controlled by TCO and ESF Constructor.

10. OTHER INFORMATION

Other information related to this test is contained in scientific notebooks maintained by the project scientists and will be included as portions of a record package or in the final records packages documenting this activity during closeout.

11. REFERENCES

Ahlers, C.F.; Shan, C.; Haukwa, C; Cohen, A.J.B.; and Bodvarsson, G.S. 1996. *Calibration and Prediction of Pneumatic Response at Yucca Mountain, Nevada, Using the LBNL/USGS Three-Dimensional, Site-Scale Model of The Unsaturated Zone.* Yucca Mountain Project Level 4 Milestone OB12M. Berkeley, California: Lawrence Berkeley National Laboratory. MOL.19970206.0285. DTN: LB960801233129.001 (Q).

Bodvarsson, G.S.; Bandurraga, T.M.; and Wu, Y.S. eds. 1997. *The Site-Scale Unsaturated Zone Model of Yucca Mountain, for the Viability Assessment.* Yucca Mountain Project Level 4 Milestone SP24UFM4; Report LBNL-40376. Berkeley, California: Lawrence Berkeley National Laboratory. MOL.19971014.0232.

Mitchell, A. 2001. *Field Work Package for Moisture Studies in the ESF* ,OCRWM Plan: FWP-ESF-96-004, Rev. 6. MOL.20010425.0002

Persoff, P. 2001. *Technical Work Plan for Unsaturated (UZ) Flow and Transport Model Report*. OCRWM Plan: TWP-NBS-HS-000001, Rev. 01. MOL.20010404.0007

MOL.20020117.0200

QA:QA

Bechtel SAIC Company, LLC

Test Plan For:
Niche 5 Seepage Testing
SITP-02-UZ-002 REV 00
WBS Element 1.2.22.4.U (Work Packages P4D1224UF1)

Prepared by:

Robert C. Trautz — 12-12-01 Date
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Approved by:

Mark T. Peters — 1/02/02 Date
Manager, Science and Engineering Testing Department

Enclosure 2

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REVISION/ADDENDUM HISTORY

Revision Number	Addendum/ Addendum Revision Number	Effective Date	Purpose of the Revision or Addendum
00	0	01/17/2002	Initial issue

DISCLAIMER

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FIGURES

TABLES

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1. INTRODUCTION

In accordance with the requirements specified in AP-SIII.7Q, this test plan (SITP-02-UZ-002) provides additional detail for ongoing seepage tests, which is part of the unsaturated zone (UZ) field testing program being performed in the Enhanced Characterization of the Repository Block (ECRB) Cross Drift. This test plan describes work to be performed at Niche CD 1620 (also known as Niche 5), located at construction station 16+20 of the Cross Drift and outside of the bulkheaded section of the ECRB (Figure 1). It enhances other moisture-monitoring studies currently ongoing in the Exploratory Studies Facility (ESF) and elsewhere in the ECRB. The study described herein is designed to study processes related to UZ flow around and seepage into a sealed drift by releasing water in boreholes above the opening.

2. PRODUCT SUPPORTED

This test plan will be covered under the *Technical Work Plan for Unsaturated Zone (UZ) Flow and Transport Model Report* (Bechtel SAIC Company, LLC (BSC) 2001), and the *Field Work Package for Moisture Studies in the ESF* (YMP 2001) and supports the Site Recommendation Product (WBS element 1.2.21.3.U) and the License Application Product (WBS element 1.2.22.4.U). (Note that technical work plan TWP-NBS-HS-000003 will supersede BSC (2001) when completed). While some of the modifications described in this test plan can support the Site Recommendation, much of the data from active testing and passive monitoring will be available to support Analysis and Modeling Reports (AMRs), the Unsaturated Zone Flow, Transport and Coupled Processes Model Report (PMR), engineering design packages, and chapters of the License Application (LA).

3. QUALITY ASSURANCE AND INTEGRATED SAFETY MANAGEMENT SYSTEM PROGRAM

This test will be performed in full compliance with the Office of Civilian Radioactive Waste Management Quality Assurance (QA) and Integrated Safety Management (ISM) requirements. Section 4 *Moisture Studies in the ESF* of YMP (2001) describes various aspects of the Environment, Safety, and Health (ES&H) requirements and compliance. YMP (2001) also contains a hazard analysis for testing activities.

3.1 APPLICABLE QA PROCEDURES

The following key QA procedures apply fully or in part to activities associated with preparing and implementing this test plan. (This list may not be all inclusive). If any of the key implementing procedures are superceded (or revised), the work shall be accomplished in accordance with the new or revised procedure.

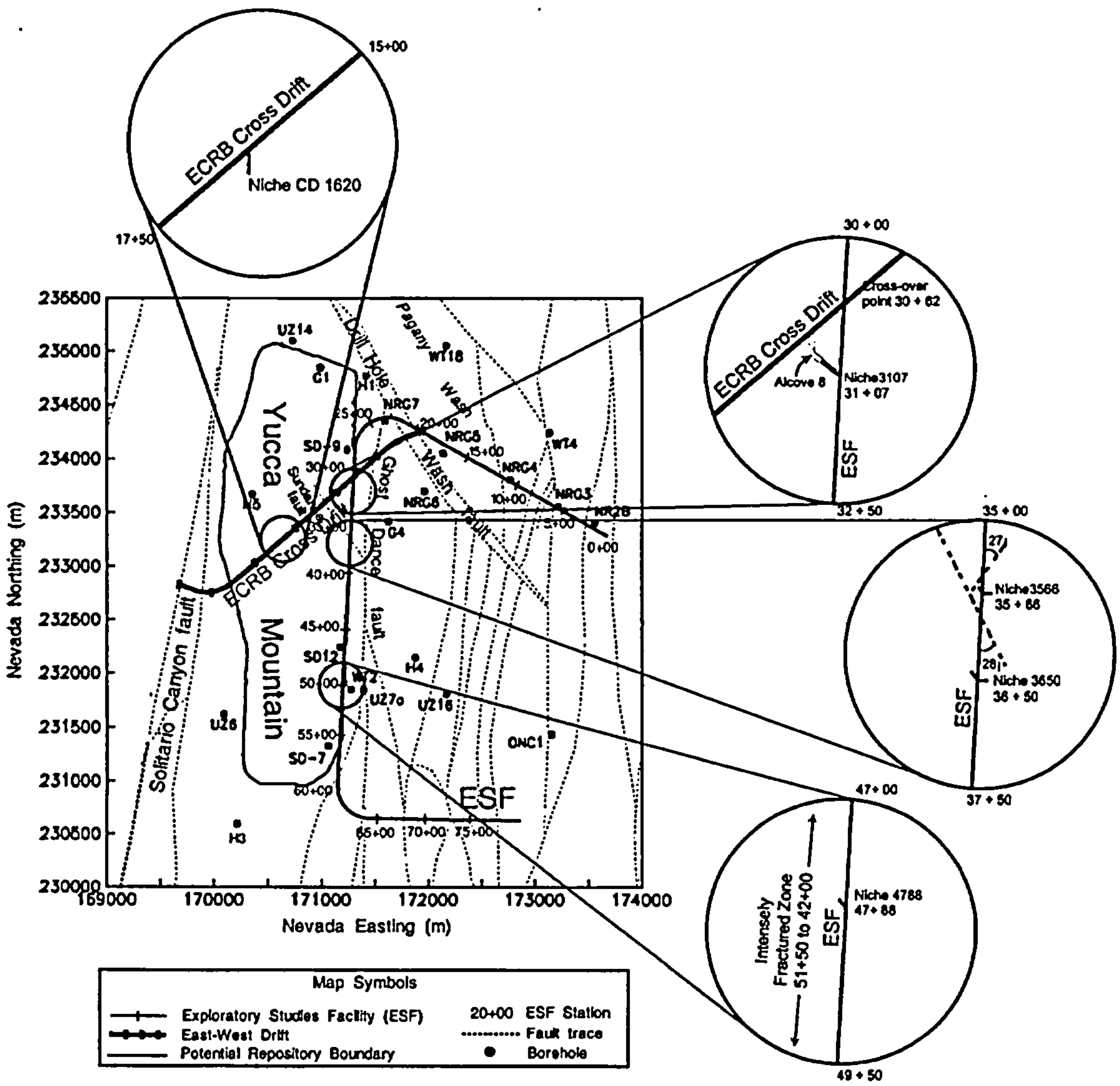

Figure 1. Schematic Illustration of Location Map for Niches 3107, 3566, 3650, 4788 and CD1620

3.1.1 Test Plan

AP-SIII.7Q Scientific Investigation Laboratory and Field Testing

3.1.2 Test Controls

AP-3.10Q Analysis and Models

AP-3.11Q Technical Reports

AP-3.12Q Calculations

AP-5.2Q Testing Work Packages AP-SI.1Q Software Management

AP-SIII.1Q Scientific Notebooks

AP-SV.1Q Control of the Electronic Management of Data

All activities in the field will be coordinated with the Technical Coordination Office (TCO).

3.1.3 Record Controls

AP-SIII.3Q Submittal and Incorporation of Data to the Technical Data Management System

AP-17.1Q Record Source Responsibilities for Inclusionary Records

All records will be submitted to the Record Processing Center (RPC) in records packages.

3.1.4 Equipment/Instrument Calibration Records/Samples

AP-7.6Q Procurement of Items and Services

AP-7.7Q Acceptance of Items and Services

AP-12.1Q Control of Measuring and Test Equipment and Calibration Standards

YAP-SII.2 Requesting Samples for Examination at the Yucca Mountain Site Characterization Project Sample Management Facility

YAP-SII.4 Collection, Submission, and Documentation of Non-core and Non-cuttings Samples to the Sample Management Facility for Site Characterization

Calibration services will be procured through BSC from qualified vendors.

3.1.5 Inspections and Audits

AP-16.1Q Management of Conditions Adverse to Quality

3.1.6 Nonconformance and Corrective Actions

AP-15.2Q Control of Nonconformances

4. PURPOSE AND OBJECTIVE

4.1 PURPOSE OF TESTING

This study uses active testing and passive monitoring in the drifts and surrounding rocks to quantify moisture movement around and seepage into drifts constructed in the lower lithophysal zone of the Topopah Spring welded tuff (Tptpll). Refer to Section 5.3 for specific test objectives, activities, and tasks.

4.2 APPLICATION OF TEST RESULTS

Data collection efforts improve the understanding of seepage processes and help to quantify the uncertainties associated with seepage into drifts. These insights provide a better understanding of UZ flow, transport, and coupled processes as well as seepage processes. The field data are used to calibrate and validate the seepage calibration model (CRWMS M&O 2001), an inverse model used to estimate important flow and seepage process-related rock properties. The estimated properties derived from the inverse seepage calibration model are then used, along with many other sources of project data and information, in performance-assessment models (CRWMS M&O 2000 and CRWMS M&O 2000a) to predict repository performance.

5. WORK SCOPE

5.1 PRODUCT DESCRIPTION

This test plan provides additional detail for seepage tests in the ECRB Cross Drift at Niche CD 1620 covered in BSC (2001). (Note that technical work plan TWP-NBS-HS-000003 will supersede BSC (2001) when completed). This test plan covers a specific portion of the overall work activities.

Products generated as a result of implementing this test plan include acquired data documented in records including scientific notebooks, equipment logbooks, and/or electronic files. Records will be submitted to the technical database management system (TDMS) and RPC in accordance with procedures identified in Section 3.1.3.

5.2 RESPONSIBILITIES

The work will be performed by the Science and Engineering Testing Department and the UZ Department, Science and Analysis Project, BSC.

5.3 ACTIVITIES, OBJECTIVES AND TASK DESCRIPTION

Seepage tests performed in the Cross Drift and in the ESF are intended to measure hydrologic conditions, parameters, and processes leading to moisture movement into and around an underground opening or drift. Test objectives, activities, and tasks include:

1. Conducting seepage tests at Cross Drift Niche 1620 (#5), located in the lower lithophysal zone, with liquid-release rates above the seepage thresholds and collect both transient data and the steady- or quasi-steady-state rate data. Determine seepage thresholds by conducting tests at progressively lower rates until no seepage is observed.

2. Evaluating memory effects associated with successive tests for flow paths retaining liquid saturation from previous tests.

3. Conducting seepage threshold tests under controlled humidity conditions to quantify the effects of ventilation-induced evaporation.

4. Instrumenting additional excavated space on the walls to evaluate wetting-front arrival and seepage diversion.

5. Analyzing and evaluating air-injection data and conducting additional tests to further characterize the test site or to confirm testing results in rock with extensive lithophysal cavities and with friable tuff matrix.

6. Improving equipment and testing methodology for more automated test execution. Compare air-permeability and seepage-threshold data from Niche CD 1620 in lower lithophysal tuff unit with data collected in Niches 3107, 3650, and 4788 of the Exploratory Studies Facility (ESF) Main Drift in the middle nonlithophysal tuff unit.

7. Collecting additional data at niches for comparison and verification, if needed.

8. Submitting verified data to technical databases to provide inputs for model calibration and assessment.

5.4 SCHEDULE

Test plan approval is scheduled to be completed by 12/15/01, and will mark the official start of test activities. Qualification of LABVIEW routines (currently under development), which are used to control test equipment and acquire test data, will be completed by 2/15/02. Test equipment currently under development will also be completed by this date. Mobilization, installation, and pre-experiment shake-down testing of the field test equipment will occur from 2/15/02 to 3/15/02. These activities must be completed before seepage testing can begin.

Individual seepage tests performed on a given test interval take from 4 to 30 days to complete. Test duration depends upon injection rates, stabilization of seepage rates into the drift, and formation transmissivity and storage properties, which can vary considerably from one test location to the next. Three to four individual seepage tests are conducted at different injection rates on each test interval to determine the seepage threshold. Therefore, from 30 to 120 days of testing are typically needed to establish a seepage threshold for each test interval. Approximately 16 to 18 months of testing (3/15/02–9/15/03) at Niche CD 1620 is needed to produce a data set that can then be used in the seepage calibration model (refer to Section 6.1) to adequately characterize seepage-relevant parameters.

Data collected during the period 3/15/02–4/1/02 will be submitted as an initial data feed to the TDMS as currently planned. Subsequent data submittals will follow, but the dates for these submittals have yet to be determined. This schedule is subject to revision due to changes to program funding, changes to QA, health and safety, and/or administrative procedures, guidelines, and/or directives that impact implementation of this work, delays in test plan and software approvals, or other like-conditions outside of the investigator's control.

6. SCIENTIFIC APPROACH/ TECHNICAL METHODS

6.1 PRE-TEST CALCULATION/ANALYSIS/MODEL PREDICTIONS

Acquired data generated as a result of implementing this test plan will be used as input to the seepage calibration model (SCM) described in analysis and modeling report CRWMS M&O (2001). CRWMS M&O (2001) describes in extensive detail the SCM and the analysis and modeling approach used to analyze acquired data obtained from previous seepage tests. A similar, if not identical approach, is expected to be used when the Niche CD 1620 data are collected and CRWMS M&O (2001) is revised. In brief, the approach involves using liquid-release and seepage rate data collected during the experiments to calibrate a 3-dimensional, drift-scale, heterogeneous permeability, continuum model, referred to as the SCM. Seepage-relevant, model-dependent parameters, including formation porosity and capillary strength, are determined by joint inversion employing the SCM, test data, and the automatic calibration feature of iTOUGH (Finsterle 1999). The SCM is tested by predicting the seepage rate for experiments whose data were not used for model calibration. The seepage-relevant parameters developed using the SCM become input to performance assessment models documented in detail in CRWMS M&O (2000) and CRWMS M&O (2000a).

6.2 TEST METHODOLOGY

Field testing and associated modeling is the basic approach for gaining knowledge and understanding of the UZ and seepage processes, and for quantifying uncertainties associated with repository performance. The modeling approach is provided in detail in CRWMS M&O (2001), as noted in Section 6.1, and will not be repeated here. A general overview of the testing methodology follows.

The objectives of the Niche CD 1620 study are realized through a combination of field experiments, including air injection and liquid-release tests, seepage tests, and passive monitoring of ambient hydrologic conditions. This test plan focuses on post-niche construction seepage tests.

Test Configuration

Seven 15 to 17 meter (m) long boreholes were drilled at the Niche CD 1620 site (shown in Figures 2 through 4) prior to niche construction in January 2000. Each borehole is nominally 0.0762 m (3 inches) in diameter, with the exception of borehole ECRB-Niche1620#7, which was mistakenly drilled to a nominal diameter of 0.1016 m (4 inches) using a larger-diameter core bit. (Boreholes will be referred to hereafter by number only (e.g., #7) and not by their full designation (e.g., ECRB-Niche1620#7) to make the document easier to read). Post-excavation seepage tests will not be performed on borehole #7 because the straddle packer system used to isolate the injection zone is not designed to fit the larger diameter hole.

The first borehole (designated #1) was installed at the approximate position shown in Figures 2 through 4. Dye-spiked water was released into eight 0.3 m long test intervals within this borehole prior to niche construction. The position of the dye within the rock was then photographed and mapped during niche excavation, and borehole #1 was intentionally removed during the mining process.

A set of three boreholes (designated #2, #3 and #4) were drilled parallel to the axis of the niche in the same horizontal plane, located about 1.0 to 1.3 meters (m) above the opening of the niche. These boreholes are collectively referred to as the horizontal boreholes. The horizontal boreholes are spaced approximately 1 m apart.

A second set of three boreholes (designated #5, #6, and #7) were also drilled parallel to the niche axis, but at a 6 to 8 degree angle upward. These boreholes are collectively referred to as the inclined boreholes. The collar of the inclined boreholes are located directly above and within 0.4 to 0.5 m of the horizontal boreholes. The upper boreholes are inclined so that the distance between the boreholes and the niche ceiling varies from about 1.4 to 3.0 m. In combination with the horizontal boreholes, the scale of the post-excavation seepage tests can vary from 1.0 to 3.0 m, the latter measurement being slightly larger than the radius of the niche.

A mechanical excavator called a roadheader was used to mine out the rock creating Niche CD 1620 in May 2000. The niche is approximately 15.5 m long by 4 m wide by 3.3 m high (Figures 2 through 4). Niche CD 1620 was constructed along the south side of the Cross Drift (at the location shown in Figure 1) within the lower lithophysal zone of the Tptpll. Water was used during niche construction to suppress dust generated during mining activities.

In May 2001, construction began on two slots located in the side walls of the niche. The original intent was to construct a 6 m long by 1 m high by 1.5 m deep slot (with an angled ceiling) in each wall of the niche to aid in the collection of water resulting from the lateral movement of water around the opening during the seepage tests. Unstable rock conditions, however, caused sections of the initial slot excavation to collapse, resulting in an opening that did not meet the desired construction and testing specifications. Construction activities were abandoned after the miners created a 2 to 3 m long irregular-shaped excavation in the left wall of the niche.

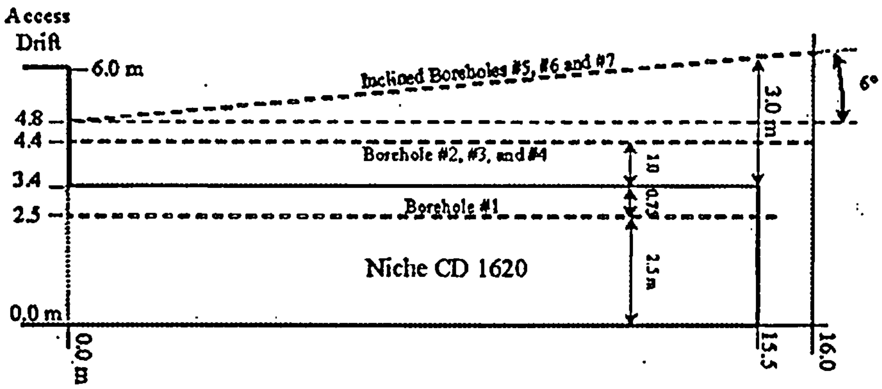

Figure 2. Side View Schematic Illustration of the Boreholes at Niche CD 1620

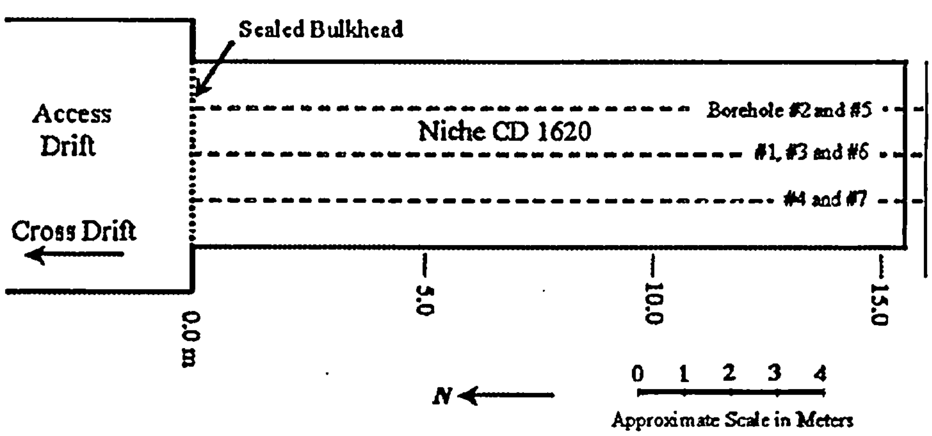

Figure 3. Plan View Schematic Illustration of the Boreholes at Niche CD 1620

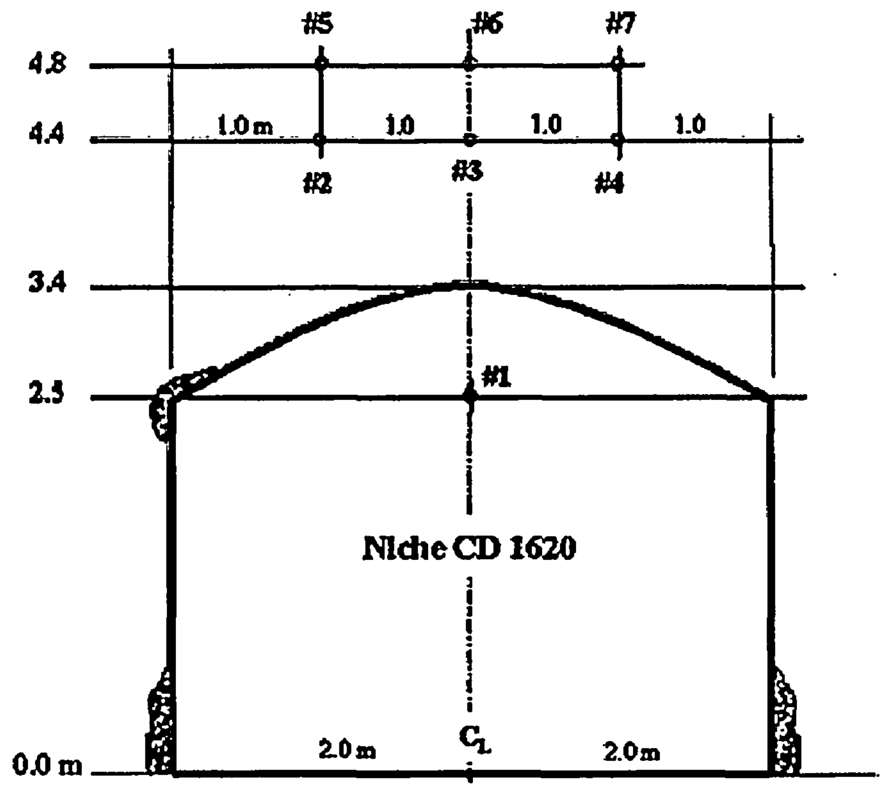

Figure 4. Schematic Illustration of Front View of Niche CD 1620 Facing South Showing Location of Boreholes (#1–7)

Ground support consisting of rock bolts was installed in the ceiling of the niche immediately following niche excavation and prior to slot construction to help stabilize the underground opening. The pilot hole for one of these rock bolts struck test boreholes #2 and #5. Unfortunately, a rock bolt was subsequently installed in the pilot hole blocking both test boreholes at a depth of 5.6 m from their collars, rendering the remaining 10 m of each borehole inaccessible. To proceed with testing using the slot for wetting-front quantification, the blocking rock bolts are required to be removed and the borehole cleaned or re-drilled so that the packers can reach the deeper depths. A straddle-packer assembly also got stuck in borehole #4 when air-injection tests were conducted on this hole. Numerous attempts to recover the packer were unsuccessful.

Unstable ground conditions, resulting in loose rock and debris sloughing off the walls of lithophysal cavities intersecting the boreholes, has also contributed to several "natural" borehole blockages. The boreholes were vacuumed out to remove as much debris as possible before testing began. Unfortunately, boreholes #3, #4 and #6 are blocked at approximately 12.0, 9.0, and 10.5 m, respectively, by large rocks and debris that could not be extracted during the cleaning process. Further disturbance caused by moving the straddle packers in and out of the holes tends to compound the problem. Table 1 summarizes the total depth and length of borehole currently available for testing.

Table 1. Borehole Depth Summary

Borehole Designation	Available for Testing (m)	Total Depth (m)
ECRB-Niche1620#1	--	15.4
ECRB-Niche1620#2	0–5.6	16.0
ECRB-Niche1620#3	0–12.0	15.5
ECRB-Niche1620#4	0–9.0	15.0
ECRB-Niche1620#5	0–5.6	15.9
ECRB-Niche1620#6	0–10.5	16.0
ECRB-Niche1620#7 *	NA	14.8

-- borehole was intentionally removed during niche construction
NA = not available
* borehole diameter is too large to accommodate test equipment.

Post-Excavation Seepage Tests

Seepage tests will be used to evaluate the capillary-barrier concept and to quantify the amount of water seeping into the niche from an artificial, localized source of water. In addition, the tests will be used to establish the threshold rate at or below which water would no longer seep into the mined opening.

A seepage test is typically conducted by pumping water at a constant rate from the surface through an injection line into an isolated test interval located in one of the boreholes described in Table 1. Isolation of the test interval is achieved using a straddle packer system consisting of inflatable rubber packers. Compressed air is used to expand the packers, pressing the rubber gland against the wall of the borehole and effectively sealing the interval between two packers from open sections of the hole.

Water is pumped from a closed container resting on a top-loading electronic balance through the injection line down hole to the isolated test interval. Electronic balances are used to monitor the cumulative mass and rate at which water is pumped into the borehole, as well as return flow (if any occurs). Water may return from the test interval back to the surface through an overflow line. Any water that returns is captured in a closed container resting on a second balance, used to monitor and record the cumulative return mass and rate. The overflow line limits the maximum ponding depth of water within the borehole to about 0.05 m, thus preventing overpressurization of the test zone by the pump. Return flow occurs when the pumping rate exceeds the infiltration capacity of the rock.

Water migrating from the release point through the rock to the niche ceiling may drip into the niche, where it is collected in a capture system. The capture system consists of several 0.3 m wide by 1.2 m long trays constructed of transparent lexan plastic hung from an aluminum frame. In turn, the aluminum frame is suspended from poles so that the top of the capture system is typically within a meter or less of the niche ceiling. The plastic trays are about 0.2 m deep and divided into four separate compartments, each 0.3 by 0.3 m square. From the compartments, water drains by gravity through a network of tubes into a closed container resting on an electronic balance. The balance is used to measure the cumulative mass of water that seeps and the seepage rate. One or more containers and balances may be employed for collecting seepage water.

Evaporation of water from containers, from the capture system, and from the wetted area of the niche ceiling during seepage tests can influence the outcome of the seepage experiments. Every attempt is made to minimize the effects of evaporation on the test results by employing the following techniques:

1. The bulkhead door at the entrance to the niche is closed and sealed during the seepage tests. This helps limit the exchange of dry air in the Cross Drift (typically <40% relative humidity) with moist air found within the niche (typically >90%).

2. Access to the interior of the niche during testing is limited to authorized field test personnel. Remote monitoring of the niche ceiling, as well as the capture trays using digital video and remote monitoring of test equipment, minimizes the number of trips inside the niche, thus limiting the exchange of air.

3. Fluid containers and transmission lines are closed systems, minimizing the effect of evaporation.

4. The potential exists for water to evaporate from the niche ceiling and diffuse into the air within the niche. Seepage water may potentially evaporate from the capture trays before the water has time to accumulate and dribble into the tubing connecting the trays to the closed container on the seepage balance(s). Therefore, the relative humidity of the air inside the niche will be artificially elevated to minimize evaporation, using a centrifugal-type humidifier capable of producing water vapor at a rate of about 1 kg per hour. Humidification will occur 24 hours per day, 7 days a week, assuming electrical power is available.

5. Electrical lighting within the niche will be minimized to limit sources of heat that enhance evaporation. Sufficient lighting must be provided, however, for video imaging of the wetted area spreading across the niche ceiling.

The temperature and relative humidity of the air inside the niche will be monitored along with the evaporation rate. A Class A evaporation pan (usually employed at weather stations) will be set on the floor of the niche and equipped with a sensitive pressure transducer to measure changes in water level caused by evaporation and/or condensation of moisture. A smaller pan, resting on an electronic balance, will also be set inside the drift to directly measure the mass evaporative flux.

6.2.1 Technical Methods

Technical methods vary according to the pertinent physical quantities to be measured and the properties to be derived. Some general requirements are summarized below, with specific requirements recorded in detail in scientific notebooks (SNs), technical implementing procedures (TIPs), technical work plans (TWPs), and field work packages (FWPs).

The SNs include:

- SN-LBNL-SCI-177-V2 (YMP-LBNL-RCT-4): Moisture Monitoring in the ESF (Phase 2) / Drift Seepage Test.
- SN-LBNL-SCI-221-V1 (YMP-LBNL-RCT-5): Moisture Monitoring in the ESF (Phase 2) / Drift Seepage Test.
- Additional scientific notebooks may be used or referred to when needed.

The current revision (at the time of conducting tests) of all TIPs will be used, to include:

- YMP-LBNL-TIP/AFT-1.0 *Balance Calibration*
- YMP-LBNL-TIP/AFT-4.0 In Situ *Mass Flux Air Permeability Testing Using Pneumatic Packers*
- YMP-LBNL-TIP/AFT-6.0 *Psychrometer Measurements*
- YMP-LBNL-TIP/AFT-8.0 *Use of Electrodes to Determine pH and Ion Concentrations in Solutions*
- YMP-LBNL-TIP/AFT-10.0 *Field Checks for the Mettler Toledo Model PG-s, PG, and SG Series of Balances*
- YMP- LBNL-TIP/AFT-11.0 *Use of ICP-AES or ICP-MS to Determine Aqueous Constituent Concentrations*
- YMP- LBNL-TIP/AFT-12.0 *Use of Ion Chromatography to Determine Aqueous Constituent Concentrations*
- YMP- LBNL-TIP/TT-9.0 *Hydrogen Isotope Analyses of Waters*
- YMP- LBNL-TIP/TT-10.0 *Analysis of the Oxygen Isotopic Composition of Water Samples using ISOPREP 18*
- YMP-LBNL-TIP GP-5.0 *Ground Penetrating Radar Data Acquisition*
- Technical implementing procedures may be added or revised, as needed.

The governing TWP for Moisture Monitoring is:

- TWP-NBS-HS-000001 Rev 01: TWP for UZ Flow and Transport PMR
- Note that technical work plan TWP-NBS-HS-000003 Rev 00 will supersede TWP-NBS-HS-000001 Rev 01 (i.e., BSC (2001)) when TWP-NBS-HS-000003 becomes effective.

The FWPs include:

- FWP-ESF-96-004 Rev. 6: Moisture Studies in the ESF
- FWP-ESF-96-001 Rev. 3: Field Test Data Collection System.

6.2.2 Measurement Requirements

Measurement requirements depend on the state of the art for sensor technology. While temperature and pressure sensors are fairly accurate and stable, relative humidity above 90% are subject to large errors. Standard sensors, together with scientific approaches using new sensors and equipment fabricated for this test, are used in the niche testing program.

6.2.3 Accuracy Requirements

For standard sensors, manufacturer-recommended accuracies are generally used as calibration requirements. High accuracy in field deployment is not easily achieved under uncontrolled field conditions. Rugged sensors with relatively low resolution are frequently chosen over delicate sensors. Standard hydrologic practices are used to infer properties from measured quantities. A rough criterion to estimate a parameter within 10% over the range of variability is specified as a general, overall guide to the quantification of accuracy needed for measurement parameters. Refined criteria can be specified for specific parameters, as documented in appropriate scientific notebooks, TIPs, TWP, and FWPs.

6.2.4 Test Instrumentation

Test instrumentation to be used is identified in the following sections. Test instrumentation and equipment may be added, replaced, or removed from service when needed. Documentation to this effect will be recorded in the appropriate scientific notebook.

6.2.4.1 Temperature Monitoring

Within drifts:

- Vaisala Humidity/Temperature Probes HMP132Y and HMP45C
- Campbell Scientific, Inc. Model 108 Temperature Probes

6.2.4.2 Relative Humidity and Wetting Front Monitoring

Within drifts:

- Vaisala Humidity/Temperature Probes HMP132Y and HMP45C
- Video imaging

6.2.4.3 Air/Liquid Flow Quantity Monitoring

Within drifts:

- TSI Alnor air-velocity transducers.

During air-permeability testing:

- Sierra Mass Flow Controllers
- Setra and/or Kavlico pressure transducers

During seepage testing:

- Mettler Toledo top loading balances
- Setra and/or Kavlico pressure transducers
- Omega liquid flow meters

6.2.4.4 Barometric Pressure

Within drifts:

- Vaisala Analog Barometer Model PTB100B.
- Setra barometric pressure transducer C270

6.2.5 Data Repeatability

Duplicated measurements are taken during calibration of many instruments, including the Mettler Toledo balances, to check the repeatability of the measurements.

6.2.6 Test Design

6.2.6.1 Design Features

6.2.6.1.1 Test Hardware

Sensors are placed within and outside of the test drift, along drift walls, and in boreholes.

6.2.6.1.2 Test Assembly

Sensors are connected to data loggers and/or personal computers operating LABVIEW.

6.2.6.1.3 Peripheral Test Hardware

Campbell Scientific Model CR-10x dataloggers and personal computers are used to acquire and store data.

6.2.6.1.4 Test Support Facility Requirements

Craft support for installation. Power reading, ventilation control, and construction water usage from the ESF Constructor. Interfaces with craft and ESF Constructor are coordinated by the TCO.

6.2.6.1.5 Power

Power required for testing will be supplied by the ESF Constructor.

6.2.6.1.6 Water/Air

A continuous supply of construction water and compressed air is required for testing.

6.2.6.1.7 Electrical

Stable and continuous AC electrical power is needed to charge data loggers and to operate seepage test equipment.

6.2.6.1.8 Craft

They are needed for test support and ventilation control.

6.2.6.1.9 Test Construction Interface

Coordinated by the TCO.

6.3 IDENTIFICATION OF COMPUTER SOFTWARE

Software used for data acquisition and equipment control includes:

- LABVIEW—used for data acquisition and test equipment control (National Instruments, Inc.)
- PC208W—used to communicate with Campbell Scientific, Inc. data loggers.

Software used for processing and/or visualization of field data include:

- LABVIEW
- Microsoft Excel.

Additional data acquisition and equipment control software may be identified, developed, and used. In addition, analytical, reporting, presentation, or modeling software used in the AMRs supported by these results will be reported in the AMRs when developed or revised. All software-related activities will be documented and controlled in accordance with the requirements of AP-SI.1Q *Software Management*, or AP-12.1Q *Control of Measuring Equipment and Test Equipment and Calibration Standards*, if applicable.

6.4 DATA RECORDING AND DATA REDUCTION

Moisture monitoring data will be recorded manually in scientific notebooks, equipment logbooks, and in electronic files, and electronically using automated data acquisition equipment. Data reduction, analyses, and modeling results will be documented in revisions to AMRs.

6.4.1 Data Collection System

Refer to Section 6.2 *Test Methodology* for a description of the data collection system. Data loggers are downloaded periodically by TCO in accordance with FWP-ESF-96-001, Rev. 3 or by LBL and documented in scientific notebooks. LABVIEW routines installed and executed on personal computers will be used to acquire electronic data and control test equipment.

6.4.1 Data Application

Refer to Sections 4.2 *Application of Test Results* and 6.1 *Pre-Test Calculation/Analysis/Model Prediction*. Data from this activity will be used as input to models and analyses documented in CRWMS M&O (2001) and CRWMS M&O (2000b).

6.4.3 Data Distribution

Data distribution is effected by periodic data submittals to the TDMS.

6.5 ANALYSIS AND MODELING DURING AND AFTER TEST

Refer to modeling and analysis approach described in Section 6.1 *Pre-Test Calculation/Analysis/Model Prediction*. The data acquired from the test will be evaluated to detect out-of-range conditions and to determine if the test is exhibiting conditions that differ from those previously observed. Periodic updates designed to be included in the appropriate AMRs will be prepared to describe the status of test and reporting results. Upon the completion of the test, the data will be reduced, analyzed and reported in the AMR listed in section 6.6.

6.6 METHODS TO RECORD DATA AND RESULTS

Moisture monitoring data will be recorded manually in scientific notebooks, equipment logbooks, and in electronic files, and electronically to data files using automated data acquisition equipment.

Data reduction, analysis results, and test interpretations will be reported in revisions to CRWMS M&O (2001) and CRWMS M&O (2000b). Additional AMRs and PMRs associated with UZ flow, transport, coupled processes, and EBS in-drift processes may also utilize the test data.

6.7 ACCURACY AND PRECISION

To ensure that the collected data meet project needs, the instruments will be calibrated in accordance with applicable procedures. The instruments for this test will be calibrated by Bechtel

Nevada Calibration Laboratory, LBNL, or procured from vendors qualified by the Yucca Mountain Project for this purpose.

6.7.1 Experimental/Sampling Artifacts

6.7.1.1 Control/Determination of Independent Conditional Variables

The independent conditional variables for this test are detailed in the test instrumentation section (6.2.4) under Test Methodology.

6.7.1.2 Control/Determination of the Boundary Conditions

A sealed bulkhead, installed across the opening of the niche, is used to control evaporation of water from the rock and capture trays inside the niche. Evaporation is further reduced by humidifying the air within the niche. Refer to Section 6.2 for additional measures taken to reduce and measure evaporation.

6.7.2 Instrument Calibration and Instrument Error

6.7.2.1 Instrument Calibration

- The expected measurement accuracy, linearity, or repeatability based on manufacturer specifications, calibration procedures of qualified vendors, or technical implementing procedures (TIPs) are identified below:
- Campbell Scientific, Inc. Model CR10X dataloggers, 0 to 2.5 V, ± 0.2 % full scale (F.S.), calibration by Bechtel Nevada Calibration Laboratory.
- Campbell Scientific, Inc. Model 108 temperature probes, polynominal linearization accuracy: typically < ± 0.5 °C at the -5 to 90 °C range Interchangeability error: typically < ± 0.2 °C over a 0 to 70 °C range, increasing to +/-0.3 °C at 95 °C, calibration by Bechtel Nevada Calibration Laboratory.
- Denver Instrument Co. Class 1 and 2 calibration weights, various weights, accuracy is dependent upon Class and actual weight value, calibration by Bechtel Nevada Calibration Laboratory.
- Kavlico pressure transducers model P155, various ranges, calibration by Bechtel Nevada Calibration Laboratory.
- Keithley Instruments, Inc., digital multimeter with selectable ranges, accuracy is based on manufacturer's specification for model used (e.g., model 2001, 2400), calibration by Bechtel Nevada Calibration Laboratory.
- Mettler Toledo model PG-s, PG and SG series balances, linearity, and repeatability are based on manufacturer's specification and are dependent upon weighing capacity of balance, calibration by LBNL using YMP-LBNL-TIP/AFT 1.0 Balance Calibration.

- Omega gas/liquid flow FLR1000 series sensors, ± 3% full scale, calibration by Bechtel Nevada Calibration Laboratory or LBNL.
- Setra Systems, Inc. barometric, gauge, differential and absolute pressure transducers, various models, ± 0.2 % F.S., calibration by Bechtel Nevada Calibration Laboratory.
- Sierra Mass Flow Controllers, various ranges, ± 1% full scale, calibration by Sierra Instruments, Inc.
- Taylor sling psychrometer, ± 0.5 °F, calibration by Bechtel Nevada Calibration Laboratory.
- Troemner calibration Class 1 and 2 calibration weights, various weights, accuracy is dependent upon class and actual weight value, calibration by Bechtel Nevada Calibration Laboratory.
- TSI Alnor air-velocity transducer: ± 2%, 0.125 - 50 m/s, calibration vendor to be developed.
- Vaisala Humidity/Temp Probes HMP132Y and HMP45C: ±2% RH(0-90%RH), ±3%(90-100%RH), calibration by Bechtel Nevada Calibration Laboratory.
- Vaisala Analog Barometric pressure transducer model PTB101B: ± 2 mbar @ 0 to 40 °C, calibration by Bechtel Nevada Calibration Laboratory.

6.7.2.2 Instrument Error

Errors associated with the manual reading of instruments and recording of data can potentially occur if these data are incorrectly entered into scientific notebooks. An automated data acquisition system (data loggers and PC-based) will be used to supplement manual reading of instruments, thus reducing these types of errors, and to ensure more frequent, unattended collection of data. Instrument-related errors associated with automated data acquisition can occur if the factors used to convert the instrument's readout (voltage, amps, etc.) to engineering units (pressure, temperature units, etc.) are incorrect or calibration factors reported by the calibration laboratory are inaccurate or entered incorrectly by the operator. All efforts will be made during the installation of the test to accurately collect and record data.

6.7.3 Handling Unexpected Results/Conditions

6.7.3.1 Unexpected Results

In the event that the observed data values or instrument behavior differ substantially from expected results, the instrument and/or data acquisition system will be inspected for visible signs of damage or tampering by unauthorized personnel. The instrument calibration and unit conversion factors will also be verified to ascertain if the conversion factors or the calibration methodology is flawed. If necessary, the test may be restarted.

Power failure within the ESF can occur because of unexpected events, including storms or accidents, or because of anticipated events, including periodic maintenance of electrical or mechanical systems. Temporary loss of electrical power is prevented by using uninterruptible power supplies (UPS) that provide a limited, temporary source of power (typically < 30–45 minutes) and help condition the AC voltage used to drive instruments and data acquisition systems. When power outages occur for extended periods of time, the limited capacity of the UPS may be exceeded and data collection will halt. If this occurs, then data collection activities will be restarted at the earliest opportunity. This may involve abandoning the test currently underway and starting a new test on a different test interval.

6.7.3.2 Unexpected Conditions

Most likely unexpected conditions are:

- Out-of-range readings from the data collection system
- Extended power failure
- Significant leakage of air through the bulkheads

Unless such conditions persist, the test will be allowed to run and data gathered at a set frequency. Unexpected conditions will be evaluated to determine their potential impact on the test and to determine whether the test needs to be modified or terminated.

6.7.4 Approach for Test Results

As mentioned in Section 4.2, data collection activities associated with the seepage-testing effort will improve the understanding of seepage processes and help to quantify the uncertainties associated with repository performance. These insights provide a better understanding of UZ flow, transport, and coupled processes, as well as seepage processes. The field data are used to calibrate and validate the seepage-calibration model and to produce estimated rock properties associated with seepage processes. If unexpected test conditions or results are identified during the modeling effort, analysts will review the results, assess the impact that the results have on how the process and natural system is modeled, modify the models if needed to better match the new results, and suggest ways of improving tests and data collection efforts. It is this iterative approach to field testing and modeling, and the feedback mechanisms of model revision and improvement resulting from data collection efforts (as well as field-test-methodology revision and improvement resulting from the modeling effort), that produce a higher quality scientific product.

7. INTERFACE CONTROL

7.1 PERFORMANCE ASSESSMENT

Total System Performance Assessment models and associated process models at the mountain and drift scales estimate and predict potential drying effects, duration of rewetting under sealed bulkhead conditions, and seepage occurrence along the drifts). With heat sources better quantified, in-drift processes can also be predicted. The processes of model prediction, calibration, and validation can improve the confidence and credibility of models used for performance assessments.

7.2 DESIGN

Designers may chose to utilize results from this test directly or depend upon calculations, AMRs, or the PMR developed to support the Engineered Barrier System (EBS) Process Models.

7.3 PROCESS MODELS

Data obtained from the test are to be evaluated in the AMRs planned for LA. Modeling of the seepage experiments is critical to the overall investigation, because it will help in the interpretation of field observations and provide input for the seepage calibration and UZ drift-scale seepage models. Data collected as a result of implementing this test plan provide input to the following process models described in detail in Sections 4.2.1–4.2.6 of BSC (2001a):

Capillary barrier effect—Lateral movement of water around and into an underground opening are caused by the presence of a capillary barrier.

Drift geometry and drift surface effect—Drift features, including wall and ceiling roughness, influence the distribution of seeps and accumulation of water at drip locations along the drift ceiling and wall.

Ventilation and condensation effects—Ventilation (or lack of ventilation) influences ambient evaporation and condensation process occurring within the drift that, in turn, influence seepage.

7.4 PARAMETERS

The *in situ* parameters that will be collected are detailed in the Test Instrumentation section (6.2.4) under Test Methodology. In general, the parameters that will be measured and evaluated *in situ* within the drift include temperature, relative humidity, barometric pressure, air flow within the niche (if ventilated), and evaporation rates. Parameters related to active air permeability and seepage testing include air-injection rates and pressures, liquid-release rates and pressures, cumulative mass of liquid released, and seepage and return rates as well as cumulative masses. Spreading of the wetted area across the niche ceiling will be recorded using time-lapse video. Release and seepage water samples will be evaluated in the laboratory for tracers when used.

8. MANDATORY HOLD POINTS

No mandatory hold points have been identified for the implementation of this test.

9. SECURITY

Test facility and data security is provided by the DOE/NV Safeguard and Security Division (SSD), YMP/BSC Security Department, and direct security support provided by Wackenhut Services (WSI). All work performed in the EBS test facility will be performed in compliance with DOE, YMP/BSC, and WSI security orders/directives.

On-site direct access to the test bed is controlled by the ESF Portal Guard Station inspecting General Underground Training (GUT) card for entries to the ESF and ECRB test facility. Periodic bulkhead entries are controlled by TCO and ESF Constructor.

10. OTHER INFORMATION

Other information related to this test is contained in scientific notebooks maintained by the project scientists and will be included as portions of a record package or in the final records packages documenting this activity during closeout.

11. REFERENCES

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