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BSC

Determination of Importance/Site Performance Protection Evaluation Interim Change Notice Cover Sheet

QA: QA

Complete only applicable items.

1. Title Determination of Importance Evaluation for Exploratory Studies Facility (ESF) Subsurface Testing Activities	2. Eval. Type ☑ DIE ☐ SPPE
3. Document Identifier (DI) Number (include revision number) BAB000000-01717-2200-00011 REV 03/ ICN 02	

4. Description of Interim Change (include list of pages involved in this ICN)

Added discussion about organic tracers used in ECRB alcoves and niches; correction to internal section references; corrected grams/liter conversion to ppm in Section 6.10.5; Clarified proposed and approved allowable limit for SF6 tracer used in testing activities; removed organic developer from sodium chlorite description; rewrote text on TFM's in Section 11.3; removed the term partially committed from Section 11.2; editorial corrections throughout; clarified text in section 11.3.6.2 to have units of grams/meter match with table. updated reference section and DIRS with latest document revisions; changed halogenated to halide when used for specific salt terminology. Labeled TFM list in Attachment II as superseded. Added Requirement #18 and supporting discussion for dust sample collection in tunnel.

The pages affected by this ICN change are

4,6,7,8,14,27,31,33,80,81,82,83,84,85,88,90,96,98,100,117,123,124,126,127,129,130,131,134,~~143~~,144, Attachment IIall pages added watermark "Attachment II superseded by BAB000000-01717-2200-00045"

SG 7/10/02

SG 7/10/02

SG 8/6/02

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20. Remarks

1. Title	2. Eval. Type
Determination of Importance Evaluation for Exploratory Studies Facility (ESF) Subsurface Testing Activities	☑ DIE ☐ SPPE

3. DI Number (include revision number)
BAB000000-01717-2200-00011 REV 03/ ICN 02

4. Rev/ ICN No.	5. Date	6. Description of Revision/ICN
00	10/29/97	Initial Issue
01	08/11/98	Revision 01 of this DIE evaluated tracer testing in Topopah Spring (TS) Loop alcove slot cuts and niches (including the construction of the alcove slot cuts), moisture monitoring stations, Alcove #1 and #7 surface infiltration testing (including new tracers for Alcove #1 testing), Geomechanics of rock mass studies, active seismic mapping experiments and geophone installations, closure(completion activities associated with the single heater test in Alcove #5, and ECRB Cross Drift testing. Interim Change Notices (ICNs) 01, 02, and 03 to Revision 00 of this DIE were incorporated. Attachment II was updated to include new tracers, fluids, and materials (TFMs) associated with the above activities. Two DIEs (DIE for Infiltration Testing into Alcoves #1 and #7 and Subsurface Geomechanics of Rock Mass Studies - BABEAF000-01717-2200-00012 Rev 00 and DIE for Niche and Alcoves Slot Cut Tracer Testing - BABEAF000-01717-2200-MI4 Rev 00) were incorporated into this Revision and were superseded in total. The Subsurface testing activities associated with the DIE for ESF and Surface-Based Active Seismic Mapping Experiments - BA0000000-01717-2200-00009 Rev 01 (Reference 14.126) were included in this DIE, but the Seismic Mapping DIE remained active until the Surface-Based portions were incorporated into the DIE for Surface-Based Testing Activities or similar DIE. Five new Quality Assurance (QA) controls were added. Updated and added various references. Made various editorial changes throughout.
02	06/01/00	Revision 02 of this DIE addressed the planned testing in the ECRB Cross Drift Cross Over Alcove (Alcove #8) and Niches #5 and #6; systematic drilling and testing planned in sections of the ECRB; installation of bulkheads in the ECRB Cross Drift at approximate ECRB Stations 17+63, 25+03, and the possible addition of a third bulkhead beyond 25+03; and several new and revised Subsurface ESF testing activities. Eliminated evaluation of Mining Methods and Air Quality and Ventilation discussions that have been removed from the Construction Monitoring Field Work Package (FWP). Replaced air quality and ventilation discussions with Radiological Monitoring discussions. Added discussions of planned laser strain monitoring of tunnel stability and water inclusion testing. Coordination of testing activities by the Test Coordination Office TCO) was emphasized in Section 13.2.42. Previous discussion of construction related activities and associated controls related to TS Loop niches and alcove slot cuts has been incorporated into Reference 14.1 and, as such, been eliminated from this DIE. The Attachment II TFM list was updated and additional groups were added to cover the ECRB Alcove, Niche, and Systematic Drilling testing activities. Revision 02 also incorporated and superseded ICNs 01 and 02 to Revision 01 of this DIE. ICN 01 addressed the addition of new boreholes in the TS Loop to validate Chlorine-36 testing and an update to the TFM list in Attachment II.

3. DI Number (include revision number)
BAB000000-01717-2200-00011 REV 03/ ICN 02

4. Rev/ ICN No.	5. Date	6. Description of Revision/ICN
03	09/21/01	Revision 03 of this DIE updates water loss limits and updates and expands earlier limits on use of fluorobenzoic acids as tracers in the ECRB Alcove # 8 /Niche#3 based on new information. Planned Cross-Drift Thermal Testing in ECRB Alcove # 10 is addressed in this DIE regarding construction controls, testing setups, and testing controls. Significant editorial changes were made to the reference section and throughout the document to be compliant with the Ensure Defensible Documents initiative. Changed Safety Assurance (SA) Department back from Systems Engineering (SE) teamresponsible for DIEs (SE DIE team) to Safety Assurance (SA) Department throughout. Updated Attachment II of the DIE with newly approved TFM's . Discussion evaluating thepreliminary results of water injection in the back of Alcove #8 to determine penetration between Alcove #8 and Niche #3 has been added to this DIE. Deleted Requirement 17 from Rev 02 of this DIE and added site specific water controls for Alcove #8/Niche#3 to Requirement 3 as 3c. Added discussion of geotechnical testing in the TS Loop and the ECRB.
03/ICN1	5/10/02	Added After-the-Fact Evaluation including references for Viton Packer HF Generation Changed reference for Liu Predictive Model for Alcove 8 infiltration test Added quantity and concentration limits to Alcove # 8 TFM list Modified wording in Section 11.1.5 to clarify control limits
03/ICN2	6/11/02	Added discussion about organic tracers used in ECRB alcoves and niches; correction to internal section references; corrected grams/liter conversion to ppm in Section 6.10.5; Clarified proposed and approved allowable limit for SF6 tracer used in testing activities; removed organic developer from sodium chlorite description; rewrote text on TFM's in Section 11.3; removed the term partially committed from Section 11.2; editorial corrections throughout; clarified text in section 11.3.6.2 to have units of grams/meter match with table. updated reference section 14 and DIRS with latest document revisions; changed halogenated to halide when used for specific salt terminology.Minor editorial changes throughout. Labled TFM list in Attachment II as superseded with watermark, added DIE requirement #18 and supporting dicussion for dust sample collection in tunnel.

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TABLES

1. PURPOSE

This Determination of Importance Evaluation (DIE) applies to the Subsurface Exploratory Studies Facility (ESF), encompassing the Topopah Spring (TS) Loop from Station 0+00 meters (m) at the North Portal to breakthrough at the South Portal (approximately 78+77 m), and ancillary test and operation support areas including the Enhanced Characterization of the Repository Block (ECRB) Cross Drift. This evaluation applies specifically to site characterization testing activities ongoing and planned in the Subsurface ESF. ESF site characterization activities are being performed to obtain the information necessary to determine whether the Yucca Mountain Site is suitable as a geologic repository for spent nuclear fuel and high-level radioactive waste. A more detailed description of these testing activities is provided in Section 6 of this DIE. Generally, the construction and operation of excavations associated with these testing activities are evaluated in the DIE for the Subsurface ESF (CRWMS M&O 1999a) and the DIE for the ESF ECRB Cross Drift (CRWMS M&O 2000a).

The scope of this DIE also entails the proposed Unsaturated Zone (UZ) Transport Test at Busted Butte. Although, not a part of the TS Loop or ECRB Cross Drift, the associated testing activities are Subsurface testing activities. Busted Butte is located to the south south-east of the TS Loop and is outside the Conceptual Controlled Area Boundary (CCAB). These activities provide access to the Calico Hills (CH) geologic structure. In the case of Busted Butte, construction and operation of excavations are evaluated herein (since this activity was not previously evaluated in CRWMS M&O 1999a).

The objectives of this DIE are to determine whether Subsurface ESF testing, and associated activities, could potentially impact site characterization testing and/or the waste isolation capabilities of the site. Controls needed to limit any potential impacts are identified in Section 13. The validity and veracity of the individual tests, including data collection, are the responsibility of the assigned Principal Investigator(s) (PIs) and are not evaluated in this DIE.

This DIE focuses on integrating and compiling the evaluations of previous DIEs which were prepared for various ESF subsurface testing activities, including the use of temporary items currently located or being developed for these testing activities (see Table 1.1), and to provide a bounding evaluation for potential future ESF subsurface testing activities that are sufficiently similar to the generic testing activities addressed herein. Subsurface testing activities items/facilities evaluated herein include: ongoing and planned testing in the TS Loop, alcoves, and niches, planned testing in the ECRB Starter Tunnel, borehole drilling and workover, and tracers, fluids, and materials (TFM) usage. Detailed identification of individual testing items/facilities and generic descriptions for subsurface-testing-related activities are provided in Section 6.

The conclusions and requirements of this DIE conservatively bound the conclusions and requirements of previously approved DIEs for the ESF subsurface testing activities addressed herein, based on conservative engineering judgement and on concurrence with this DIE (via a formal review process) by the originating and reviewing organizations of the previously approved evaluations. Hence, this DIE supersedes the following DIEs listed in Table 1.1.

Table 1.1. Superseded DIEs

Type of Document	Title	Document Identifier	Date
DIE	DIE for ESF and Surface-Based Active Seismic Mapping Experiments	BA0000000-01717-2200-00009 REV 01/ ICN 01	5/14/98; 6/4/98
DIE	DIE for the Use of Additional Water in Alcove #1 Infiltration Testing	BAB000000-01717-2200-00019 REV 00	11/1/99
DIE	DIE for Perched Water Testing	BAB000000-01717-2200-00109 REV 01	10/21/95
DIE	DIE for Consolidated Sampling	BAB000000-01717-2200-00110 REV 01	10/21/95
DIE	DIE for Geologic Mapping	BAB000000-01717-2200-00112 REV 01	10/21/95
DIE	DIE for Hydrochemistry Tests, Radial Borehole Tests, and Hydrologic Properties of Major Faults Encountered in the ESF	BAB000000-01717-2200-00146 REV 02	9/13/96
DIE	DIE for the Moisture Studies in the ESF	BAB000000-01717-2200-00151 REV 00	6/14/96
DIE	DIE for Laser Strain Measurement/ Deformation Monitoring Testing	BABDC0000-01717-2200-00001 REV 00	11/29/99
DIE	DIE for the Exploratory Studies Facility Alcove #2 Exhibit Area	BABEA0000-01717-2200-00001 REV 00	5/27/97
DIE	DIE for Phase I Testing in the TS Main Drift Thermal Testing Facility	BABEAF000-01717-2200-00003 REV 01	11/14/96
DIE	DIE for Hydraulic Fracture Testing in the Exploratory Studies Facility Thermal Testing Facility	BABEAF000-01717-2200-00004 REV 00	9/17/96
DIE	DIE for Testing in the ESF Thermal Testing Facility Heated Drift	BABEAF000-01717-2200-00006 REV 01	12/20/96
DIE	DIE for the ESF Drift-Scale Flux and Niche Study	BABEAF000-01717-2200-00007 REV 01	4/1/96
DIE	DIE for Confirmation Drilling in the Exploratory Studies Facility	BABEAF000-01717-2200-00008 REV 00	2/18/97
DIE	DIE for Ground Support in the Vicinity of Fault Zones	BABEAF000-01717-2200-00009 REV 00	5/16/97
DIE	DIE for Infiltration Testing into Alcoves #1 and #7 and Subsurface Geomechanics of Rock Mass Studies	BABEAF000-01717-2200-00012 REV 00	12/19/97
DIE	DIE for Niche and Alcoves Slot Cut Tracer Testing	BABEAF000-01717-2200-00014 REV 00	6/29/98

Revision 01 of this DIE addressed several new and revised Subsurface ESF testing activities. These included tracer testing in alcove slot cuts and niches, moisture monitoring stations, Alcove #1 and #7 surface infiltration testing (including new tracers for Alcove #1 testing), geomechanics of rock mass studies, active seismic mapping experiments and geophone installations, closure/completion activities associated with the single heater test in Alcove #5, and ECRB Cross Drift testing. Revision 01 also incorporated Interim Change Notices (ICNs) 01, 02, and 03 to Revision 00 of this DIE. ICN 01 addressed the planned testing activities in the TS Main Drift at the ECRB Cross Drift cross over point and updated the TFM list in Attachment II. ICN 02 expanded the TFM list to include additional TFMs required for UZ Transport Testing at Busted Butte. ICN 03 expanded the use of concrete on the Alcove #5 invert for safety purposes. The two DIEs added to Table 1.1 above (BABEAF000-01717-2200-00012 REV 00 and BABEAF000-01717-2200-00014 REV 00) have been incorporated in this revision and are superseded in total. The subsurface testing activities associated with the DIE for ESF and Surface-Based Active Seismic Mapping Experiments, BA0000000-01717-2200-00009 REV 01 are included in this DIE (this DIE is included in Table 1.1 for completeness as noted below).

Revision 02 of this DIE addressed the planned testing in the ECRB Cross Drift Cross Over Alcove (Alcove #8) and Niches #5 and #6; systematic drilling and testing planned in sections of the ECRB; installation of bulkheads in the ECRB Cross Drift at approximate ECRB Stations 17+63, 25+03, and the possible addition of a third bulkhead beyond 25+03; and several new and revised Subsurface ESF testing activities. Eliminated evaluation of Mining Methods and Air Quality and Ventilation discussions that have been removed from the Construction Monitoring Field Work Package (FWP). Replaced air quality and ventilation discussions with Radiological Monitoring discussions. Added discussions of planned laser strain monitoring of tunnel stability and water inclusion testing. Coordination of testing activities by the Test Coordination Office (TCO) was emphasized in Section 13.2.42. Previous discussion of construction related activities and associated controls related to TS Loop niches and alcove slot cuts has been incorporated into CRWMS M&O (1999a) and, as such, been eliminated from this DIE. The Attachment II TFM list was updated and additional groups were added to cover the ECRB Alcove, Niche, and Systematic Drilling testing activities. Revision 02 also incorporated and superseded ICNs 01 and 02 to Revision 01 of this DIE. ICN 01 addressed the addition of new boreholes in the TS Loop to validate Chlorine-36 testing and an update to the TFM list in Attachment II. ICN 02 addressed the addition of new boreholes in the ECRB Cross Drift for air-permeability and blast effects testing near Niche #5, supplemental information associated with the Chlorine-36 validation testing, and added additional items to the TFM list in Attachment II. The three DIEs added to Table 1.1 above (BA0000000-01717-2200-00009 REV 01/ICN 01 [noted in Revision 1 discussion above], BAB000000-01717-2200-00019 REV 00, and BABDC0000-01717-2200-00001 REV 00) have been incorporated in this revision and are superseded in total. Changed Safety Assurance (SA) Department to System Engineering (SE) team responsible for DIEs (SE DIE team) throughout. Significant editorial changes were made to the reference section and throughout the document to be compliant with the Ensure Defensible Documents initiative. Change bars were only used to indicate new references in the reference section, format changes were not change barred. Revision 03 of this DIE changes the Systems Engineering (SE) team back to the Safety Assurance (SA) team responsible for DIEs throughout. Change bars have been used to indicate editorial changes, new TFM approvals, new text, and new (or updated) references in the reference section. This DIE updates Alcove #8 water loss limits and updates and expands earlier limits on use of fluorobenzoic acids as tracers in the ECRB Alcove #8/Niche #3 based on new information. In addition this Revision 03 considers Alcove #10 testing.

2. QUALITY ASSURANCE

This evaluation was prepared using Civilian Radioactive Waste Management System (CRWMS) Management and Operating Contractor (M&O) implementing line procedure LP-SA-001Q-BSC, *Determination of Importance and Site Performance Protection Evaluations,* subject to the requirements of the United States Department of Energy (DOE) Office of Civilian Radioactive Waste Management Quality Assurance Requirements and Description for the Civilian Radioactive Waste Management Program (DOE 2000). A Technical Work Plan has been prepared in accordance with AP-2.21Q, *Technical Work Plan for: Testing and Monitoring,* (BSC 2001a). This DIE is quality-affecting because it establishes the applicability of the Quality Assurance (QA) program to the evaluated ESF subsurface testing activities with specific regard to potential impact to site characterization data, the waste isolation capabilities of a potential geologic repository at the Yucca Mountain site, and other permanent, Q-List (YMP 1998a) items (which have been classified QA-1, QA-2, and QA-5, including natural barriers) that have been constructed or installed at the Yucca Mountain site. Pursuant to the requirements of Title 10 of the Code of Federal Regulations, Part 63 (10 CFR 63), Section 15), QA controls for minimizing, to the extent practical, any potential for impacts (as identified herein) to permanent, classified items, including potential impacts associated with the use of temporary items, are also established by this DIE.

3. METHODOLOGY

This evaluation was performed in accordance with procedure NLP-2-0. This is a Category-III DIE since it addresses field activities that are potentially significant with respect to the Q-List (YMP 1998a) items and site characterization data and, as a result of consolidating all Subsurface ESF testing activities into a single, stand alone DIE, will not have an applicable, active category III DIE or analogous precedent. The DIE is prepared by: (1) reviewing the best available design information (as discussed in this section) related to surface/subsurface construction, operation, maintenance, and reclamation activities associated with the ESF Subsurface Testing items/facilities; (2) evaluating the potential of these items and activities to affect Q-List (YMP 1998a) items and site characterization testing; and (3) establishing QA controls where necessary to minimize potential impacts on Q-List (YMP 1998a) items and site characterization activities to the extent practical.

For the ESF Subsurface Testing sites identified in Section 6 of this DIE, many of the activities evaluated herein were completed before the approval of this DIE. Hence, the QA controls developed in Section 13 are intended to be applied commensurate with the current status of the ESF Subsurface Testing site.

The best available information related to ESF Subsurface Testing items/facility construction, operation, maintenance, reclamation, and testing activities includes but is not limited to: M&O preliminary approved design documents and revisions to construction drawings and specifications for subsurface accommodations, FWPs, Testing Study Plans, TCO/PI criteria letters, the Yucca Mountain Site Characterization Project (YMP) Site Atlas (DOE 1997), and applicable e-mails. In cases where inputs from these documents provide critical characteristics that could potentially impact the conclusions and derived requirements of this evaluation, specific reference citations are provided in the text.

After approval of this DIE, implementing documents (e.g., FWPs, design specifications, and design drawings) will be reviewed by the SA DIE team. These reviews are conducted to: (1) ensure that the original basis for the evaluation (i.e., best available design information) adequately bounds the final scope of activities to be conducted in the ECRB Cross Drift, and (2) verify that any applicable DIE requirements have been properly integrated into the implementing documents.

4. ASSUMPTIONS

4.1 It is assumed throughout this evaluation, unless specifically stated otherwise, that the minimum offset from the closest waste package emplacement area is 37 m for the TS Loop (including associated excavations) (CRWMS M&O 1995a) and Phase I (Stations 0+26.4 m to 7+73 m) of the ECRB Cross Drift (including associated excavations) and 15 m for Phase II (Stations 7+73 m to the end of the ECRB Cross Drift [approximate Station 26+81 m]) of the ECRB Cross Drift (including associated excavations) (CRWMS M&O 1997a) to establish bounding conditions for this analysis (as stated in Section 11.1.4).

4.2 In establishing the boundaries for the DIE, it is assumed that construction and other activities associated with Tunnel Boring Machine (TBM) operation, utilities installation, and support for TBM operation for construction of the ECRB Cross Drift will be in accordance with the ESF Design specifications and drawings, which implement applicable requirements of the Exploratory Studies Facility Design Requirements document (ESFDR) (YMP 1997a).

4.3 Testing support accommodations (i.e., cable runs, standard power, lighting, compressed air, ventilation, communications, Data Collection System [DCS] connection, etc.) critical to the conduct of specific tests are addressed in the FWPs developed for those tests. The DCS is supplied by the Natural Environment Program Operations (NEPO) (formerly Site Evaluation Program Operations) and is controlled under the appropriate National Laboratory QA procedures. The FWPs will also address access needed to support the testing operations as soon as practical after testing equipment is installed, or testing space is constructed. This assumption further clarifies the scope of the DIE (as stated in Section 1 and throughout the evaluation) with respect to testing activities.

4.4 The TFMs to be used in the Subsurface ESF will be those for which data (e.g., Material Safety Data Sheets [MSDSs]) have been provided and reviewed (Attachment II). TFMs that have not yet been reviewed will be evaluated in accordance with the project TFM procedure (Yucca Mountain Administrative Procedure [AP] AP-2.17Q, *Tracers, Fluids, and Materials Data Reporting and Management*). It is assumed that the MSDS or other data source recommended procedures will be followed for use, storage, handling, ventilation, spills and leaks, and personnel safety. Temporary items and materials used for the construction, operation, maintenance, and reclamation of Subsurface ESF facilities and equipment used for the conduct of testing activities that are not permanently emplaced or committed to the Subsurface ESF environment or specifically controlled by requirements contained in this DIE are exempted from the installation and removal reporting requirements contained in AP-2.17Q. This assumption establishes the scope for the DIE with respect to TFMs and is based on the ESFDR (YMP 1997a) and AP-2.17Q. (This assumption is used throughout this DIE.)

4.5 Based on the TFM procedure (AP-2.17Q), it is assumed that water used for fire suppression and control will be treated as a significant spill.

5. COMPUTER CALCULATIONS

No analytical computer programs have been used directly in the preparation of this document. Procedure AP-SI.1Q does not apply in that there are no software programs used in this DIE to manipulate data or information nor is there data or information retained for this DIE. However, computer programs have been used in some of the referenced documents that form the basis of some of the results presented in this document. Detailed discussions of these computer calculations, including their treatment under the QA Program, are provided in the referenced documents.

6. DESCRIPTION OF ITEMS/ACTIVITIES

6.1 GEOLOGIC MAPPING

Geologic mapping of the ESF is conducted to document lithologic and fracture variability throughout the underground excavations, to investigate structural features, and to provide siting data to confirm (or modify) planned test locations within the underground ESF. FWP-ESF-96-010 (YMP 2000a) provides a description of geologic mapping activities.

Typical geologic mapping activities are categorized by several tasks. Exposed rock surfaces in the ESF are photographed. Detail and line surveys are performed continuously along one rib of each drift or ramp. Detail and line surveys consist of recording the characteristics of fractures, geologic discontinuities, or other features which intersect a datum line. Regular sampling of the wall rock and fracture in-filling are performed concurrent with the mapping process. Typically, the constructor cleans the walls using a compressed air/water mist. Law (1998) describes the use of a low-flow pressure washer in the ECRB Cross Drift. This pressure washer has a constrictive nozzle aperture that applies only construction water (i.e., not mixed with air). The PI may operate additional air/mist equipment as necessary to further clean ESF surfaces. Lithium Bromide (LiBr) is the approved tracer for use in this air/water mist mixture.

6.2 CONSOLIDATED SAMPLING

Consolidated sampling is conducted in the ESF in support of site characterization activities, as described in FWP-ESF-96-009 (YMP 2000b). The purpose of the sampling program is to collect samples in the ESF for a variety of hydrologic, geologic, mechanical, and chemical tests, including Chlorine-36 studies discussed in Section 6.10. The method used to collect samples is generally by hand using a hammer and chisel. Alternate methods of sample collection are also identified such as using hydraulic splitters and drilling core samples. Sample locations are generally approved by the responsible PI before the sampling activity. Hazardous mineral assessments of rock samples and fluid inclusion testing samples will be taken for off-site analysis. Other non-intrusive samples are also taken periodically (e.g., air and mold samples) for off-site analysis.

6.3 PERCHED-WATER TESTING

Perched-water testing is planned as a contingency test and is conducted when/if perched water is encountered. FWP-ESF-96-011 (YMP 1997b) provides a description of the perched-water testing activities. The purpose of this test is to detect the occurrence of perched water, delineate its lateral and vertical extent, identify perching mechanism(s), and collect samples of the perched-water for chemical analyses. The form and duration of the testing is dependent upon the nature of any encountered perched water. It should be noted that during excavation of the TS Loop no perched water was encountered.

If perched water is encountered during subsequent excavation, one or more small-diameter boreholes may be drilled to enhance drainage, facilitate collection of water samples, and allow flow and/or pressure measurements to be made. The borehole(s) may be instrumented for long-term testing and monitoring to obtain data on hydraulic pressure over time. Periodic water sampling may be required from perched-water boreholes. Sulfur Hexafluoride (SF_6) and LiBr are the tracers identified for use in this test. (YMP 1997b)

6.4 HYDROCHEMISTRY TESTS

Hydrochemistry tests determine the chemical composition, reactive mechanisms, and age of water and gas in pores, fractures, and perched-water zones within the unsaturated tuffs accessible from the ESF and/or affiliated boreholes. The ESF provides access for the collection of gas, rock, and fracture-water samples. Hydrochemistry tests are generally conducted in association with other testing such as the radial borehole tests and hydrologic properties testing of major faults. Hydrochemistry tests are described in FWP-ESF-96-008 (YMP 1996a).

6.5 RADIAL BOREHOLE TESTS

Radial borehole tests investigate vertical and lateral movement of fluids (i.e., gas and water) within individual hydrogeologic units and across hydrogeologic unit's contacts (e.g., Tiva Canyon welded unit [TCw]-Paintbrush Tuff nonwelded unit [PTn] and PTn-Topopah Spring [TSw] contacts). Single and cross-hole tests are conducted to determine *in situ* air permeability. Radial borehole tests are described in FWP-ESF-96-007 (YMP 1996b). Boreholes are typically dry cored and extend for nominally 30 m. Gaseous tracer injection tests are also conducted. SF_6 and/or SUVA-COLD MP® (tetra fluoroethane) tracer gases are used when drilling the boreholes. Borehole geophysical and down-hole video logging is conducted after boreholes are drilled. After initial testing and instrumentation, long-term monitoring may take place for several years.

The water-injection testing using a 100 liter per minute, 100 kiloPascal pressure water injection system (as discussed in YMP 1996b) has not been evaluated in this DIE and is specifically excluded from the scope of this DIE. This activity requires additional evaluation by the SA DIE team before the conduct of this test.

6.6 HYDROLOGIC PROPERTIES OF MAJOR FAULTS ENCOUNTERED IN THE ESF

Hydrologic properties testing of major faults encountered in the ESF provides hydrologic information to quantify hydrologic properties of large structural features, such as faults, by testing on a smaller scale at selected locations accessible from the alcoves, ramps, and/or drifts in the ESF. The data collected is used in a matrix hydrologic property database that models matrix flux in Yucca Mountain under varieties of upper-boundary conditions which simulate possible climatic conditions. FWP-ESF-96-006 (YMP 1997c) describes and governs the conduct of hydrologic properties testing of major faults encountered in the ESF.

The hydrologic properties testing includes: (1) measuring pneumatic and hydraulic permeability, porosity, and anisotropy of major faults along with associated fault zones; (2) monitoring flow of gas, water, and vapor in major faults of the UZ; and (3) conducting tracer tests to estimate the tortuosity and effective porosity of faults and their associated fault zones. (YMP 1997c)

Hydrologic properties testing typically includes dry drilling activities, tracer gas injection, surveying of boreholes, and instrumentation and monitoring of the boreholes. The tracer planned for use is SF_6. However, SUVA-COLD MP® (tetra fluoroethane) is also permitted per YMP (1997c).

6.7 SEISMIC MONITORING

Seismic monitoring is primarily a Surface-Based Testing activity and is addressed in CRWMS M&O (2000b); however, certain portions of the activities described in FWP-SB-97-007 (YMP 1998b) occur in the Subsurface ESF. The purpose of the seismic monitoring program is to observe and track naturally occurring seismic activity within a grid of seismic stations surrounding and including Yucca Mountain. The program includes the installation and maintenance of these seismic station instruments as well as the capability to deploy portable instruments at multiple locations for monitoring seismic aftershocks. A strong motion seismic station is currently installed at the end of the Thermomechanical Alcove (TMA) Extension in Alcove #5.

A network of geophone receivers has also been installed in the Subsurface ESF. Per Finnegan (1998a, 1998b, 1998c), the array of geophones extends from roughly TS Main Drift Station 26+50 m to Station 60+25 m. The geophones are spaced at approximately 15-m intervals. The activity includes the wet-drilling of nominally six-inch-deep boreholes approximately one meter above the invert on the right rib. Three-inch vertical geophones are installed in each borehole along with a small quantity of Wil-X cement around the geophones. Additional seismic equipment may be added to the Subsurface ESF later, should local seismic activity dictate.

The seismic monitoring activity also includes active seismic mapping experiments. One such experiment was described in Finnegan (1998a) and included the drilling of 2 approximately 3-m deep boreholes, with an approximate 2.25-inch diameter, in the left rib of the TS North Ramp within a variance of approximately 30 m around Station 20+10 m. These boreholes were spaced at about two-meter intervals along the TS North Ramp. Approximately 10 feet of 100-grain Ensign-Bickford PRIMACORD detonating cord was loaded at the maximum depth of each borehole. Detonation of this explosive provides the seismic source. After the explosive is loaded, the boreholes are packed off with an approved stemming material. Packing off the boreholes is necessary to ensure the required seismic wave propagation. Ensign-Bickford PRIMADET Non-Electric Delay Detonators (MS Series), or an equivalent detonator were used to detonate the explosives.

Three instrumentation boreholes, with an approximate 2.25-inch diameter, were also drilled in the left rib of the TS Main Drift within a variance of approximately 30 m around Station 39+60 m. The instrumentation boreholes were spaced at about two-meter intervals along the TS Main Drift. Each instrument borehole was drilled to a unique nominal depth—one at one-half meter, one at one meter, and one at two meter. Geophones were loaded at the maximum depths of these boreholes for monitoring the explosions. Additional wall-mounted geophones were also to be attached to the left rib of the TS Main Drift within a variance of approximately 30 m around Station 39+60 m. The geophones were attached to the host rock with an approved epoxy material. Vibro-seismic trucks were also driven along established Yucca Mountain roads for the purpose of inducing seismic readings in the aforementioned geophones located in the ESF, which is bounded by CRWMS M&O (2000b).

Mitchell (2000a) describes a seismic monitoring activity associated with a surface Waste Handling Building geotechnical testing study. In this activity, a series of up to six HQ sized boreholes, approximately three meters deep, will be drilled into the right rib of the North Ramp between Alcoves #2 and #3. These boreholes will be used to install temporary seismological instrumentation.

6.8 BOREHOLE WIRELINE MEASUREMENTS

Borehole wire-line measurements are performed on numerous Subsurface ESF boreholes and coreholes. FWP-ESF-96-013 (YMP 1999a) provides a generic description of the activities involved in these measurements. The types of measurements performed include borehole video logging, caliper measurements of the borehole diameters, gamma ray surveys of background radiation, neutron surveys for porosity and saturation levels, and electron bulk density measurements. Borehole wire-line measurements support other activities such as construction monitoring, thermal testing, moisture studies, hydrologic properties, hydrochemistry test, and radial borehole tests.

6.9 CONSTRUCTION AND RADIOLOGICAL MONITORING

Construction monitoring studies are designed to provide data that will be used to assess potential repository performance and support the rock mass constitutive models developed for predicting the mechanical behavior of the repository-sized openings. FWP-ESF-96-002 (YMP 1999b) provides a description of the three primary activities described below. FWP-ESF-99-001 (YMP 1999c) provides a description of a long-term deformation monitoring study being performed in the TS South Ramp. FWP-ESF-98-001 (YMP 1999d) provides a description of radiological monitoring activities described below.

6.9.1 Access Convergence Testing

The objectives of the access convergence tests are to monitor rock-mass deformation around the accesses and to measure *in situ* stress. Rock-mass deformation around the access ramp or drift are monitored at measurement stations using multiple-point borehole extensometers (MPBXs) and single-point borehole extensometers placed at the crown and springline of the opening. Diametral convergence are measured at multiple locations in the ESF North and South Ramps, TS Main Drift, ECRB Cross Drift, alcoves, niches, and auxiliary excavations using rod or tape extensometers. Stress measurements are made at stations located near faults or other areas of interest. *In situ* stress is measured in boreholes drilled from within the north ramp test alcoves using either overcoring or other techniques. Induced stress and stress change tests are conducted in the Thermal Testing Facility (TTF) and behind the TBM using slot tests in the tunnel walls and in radial boreholes using small hydraulic powered chain saws and the Interfels Borehole slotter system. Additional stress testing is ongoing at the point where the ECRB Cross Drift crosses over the TS Main Drift. If a concrete liner is used, stations may also include pressure cells to measure radial and hoop stress changes over time as construction continues beyond the test location. If the access is unlined, load cells on rockbolts will provide an indication of support loading in place of the liner instrumentation. (YMP 1999b)

6.9.2 Monitoring of Ground Support Systems

The objectives of the monitoring of ground support systems activity are to develop recommendations for ground support methods to use in drifts in the potential repository, based on evaluations of the ground-support methods used in the ESF, and on experimentation with other ground-support configurations. This activity is conducted in ESF main openings (such as both ramps, the TS Main Drift, ECRB Cross Drift, and associated auxiliary excavations) and will be conducted in any additional ESF major drifts (such as ECRB Cross Drift and CH Drift) that may be constructed. The selection, installation, and performance of the support systems used are monitored. Experimentation with ground support includes pull tests on rockbolts and installation of rockbolt load cells. In addition, observations are made of unsupported rock; strength measurements are taken on shotcrete cores, and trials of ground-support systems (different from those currently prescribed for the ESF) may be conducted. (YMP 1999b)

6.9.3 Monitoring Drift Stability

The objectives of the monitoring drift stability activity are to: (1) provide confidence in predictions of usability of the potential repository underground facilities over their operational life, (2) contribute to the evaluations of the effectiveness of mining methods and ground supports, (3) calibrate and refine criteria to determine stability of the openings, and (4) develop techniques to monitor stability of the potential repository drifts. These tests monitor drift convergence and drift maintenance activities throughout the ESF, along accesses, at the point where the ECRB Cross Drift crosses over the TS Main Drift, and in the CH if tunnels are mined in this formation. Convergence measurement stations are selected by the PI. Where possible, convergence measurements are taken in a continuous manner. Rock-mass relaxation is investigated using MPBXs. Rock falls and maintenance activities are also documented. (YMP 1999b)

6.9.4 Deformation Monitoring

An activity related to construction monitoring involves the installation of a laser strain-monitoring device along the South Ramp of the TS Loop. The deformation monitoring activity will provide data related to the proposed repository from: (1) long-term tectonic changes, (2) earth tides, (3) free oscillations of the earth, (4) barometric pressure changes, (5) static deformations caused by local earthquakes and explosions, (6) triggered slip along nearby faults caused by transient earthquake waves and explosion strains, and (7) development of the potential repository itself, including its mining and heating. Per YMP (1999c), an approximately 500 m long vacuum tube will be installed along the right rib of the South Ramp in the vicinity of Station 65+00 to 70+00. The tube will be nominally one to three meters above the invert and will be supported by up to three monuments (two at its ends and potentially one in the middle) and various smaller brackets. The monuments are nominally one-meter deep by two-meters high by two-meters long, made using an approved cement and poured in place. Up to four small mined out sections of the right rib, nominally one-meter deep by three meters high by two meters long are required for installation of the monuments, electronics, and vacuum pump(s). The brackets will be installed using small bolts similar to those used for construction utilities in the TS Loop. Four to six boreholes, nominally four to six inches in diameter, (two at each of the two end monuments plus up to two additional instrumentation boreholes) were wet-drilled to a depth of approximately 15.2 m (nominally two tunnel diameters) for the installation of laser optical anchors (laser reflection devices). The boreholes were drilled nominally 30 degrees off-center with a line perpendicular to the rib. The boreholes were drilled nominally horizontal, with a possible slight downward angle to facilitate straighter boreholes. The borehole casing and optical anchor laser reflection devices will be grouted into these boreholes, using approved grouts, additives, and casing materials.

6.9.5 Radiological Monitoring

Monitoring of air quality and ventilation systems was previously included in YMP (1999b), but was eliminated in later revisions. The radon emanation aspects of the Subsurface ESF are now addressed by FWP-ESF-98-001 (YMP 1999d). YMP (1999d) controls radiological monitoring and data collection activities to include radon concentration, radon progeny, radioactive airborne particle, and ambient gamma measurements. Some aspects of ventilation system monitoring are also included in FWP-ESF-96-004 (YMP 2000c).

6.10 MOISTURE STUDIES

Moisture studies in the ESF are conducted to refine understanding of the moisture conditions in the Subsurface ESF, including the ECRB Cross Drift and auxiliary excavations, excavated areas and adjoining rock matrix. The purpose of moisture studies in the ESF is to: (1) document tunnel baseline conditions and effects of various construction and operating activities; (2) conduct hydrologic testing, infiltration, percolation, and seepage flux measurements, and data collection for the unsaturated and saturated stratigraphic zones exposed in the ESF; (3) use the information gathered from these studies to continue the development of process models to support system performance assessment, site recommendation, and license application; (4) determine a mass water balance for material excavated during construction; (5) provide information for hydrologic imbibition with consideration to airborne industrial hygiene issues; and (6) associate information and technical skills used for moisture studies to help correlate and assimilate additional information that could enhance the planned testing activities and the testing data that are required for performance assessment. The results of this testing are used as input to hydrologic modeling calculations for the entire Yucca Mountain area and as inputs to hydrologic models. FWP-ESF-96-004 (YMP 2000c) describes and governs the conduct of the moisture studies activities.

6.10.1 Moisture Study Boreholes, Coreholes, Monitoring Stations, and Drip Trays

Boreholes and/or coreholes are drilled and instrumented to obtain moisture information such as determinations of water potential, temperatures, rock permeability and porosity. The number and locations of the boreholes and/or coreholes are determined to provide the best coverage of the desired Subsurface ESF areas. The holes are drilled from the main tunnel/drift only (i.e., no moisture studies boreholes/coreholes are drilled from any of the testing alcoves) and are generally located below the springline of the tunnel with a slight (one to two degree) up angle to avoid fluid collection. The holes are nominally 2 to 10 m in length with an HQ-sized diameter (similar in size to a rockbolt hole). The PI may also drill short boreholes, nominally 0.5 m in length by 2.5 centimeters (cm) in diameter. The majority of the moisture studies boreholes and coreholes were drilled before the approval of Revision 00 of this DIE. However, there is a possibility of drilling additional holes. The monitoring of the emplaced instrumentation may continue for several years. (YMP 2000c)

Several semi-stationary monitoring stations are used throughout the ESF. These stations monitor air temperature, relative humidity, barometric pressure, and in some cases wind speed in selected locations in the TS Loop and ECRB Cross Drift. In addition, infrared monitoring of the tunnel walls is performed in selected locations. The information collected feeds an overall analysis of water movement in the ESF. (Parsons 1998; Scott 1998)

Drip trays may be installed in areas where significant water influx is possible. Some of these drip collection systems may be attached to the existing ground support system and would be subject to the requirements of CRWMS M&O (1996a). CRWMS (1998e) evaluates one such set of drip trays hung from existing ground support. A series of small (nominally 20 cm by ¼ inch diameter) boreholes are also instrumented at the point where the ECRB Cross Drift crosses over the TS Main Drift (Brake 1998a).

6.10.2 TS Main Drift Drift-Scale Flux and Niche Studies

Niches are evaluated as temporary testing accommodations. The location of these niches is coordinated between the TCO and the M&O's Repository Subsurface Design Organization. If the potential repository layout design is changed (after the excavation of these niches), the location of the niches must be factored into the new design, including potentially evaluating these niches as permanent accommodations. Per Hollins and Mitchell (1997), the niches will be used to: (1) measure the field permeability of proposed repository rock for use in unsaturated zone site-scale models and unsaturated zone drift-scale sub-models, (2) determine the threshold of flow into a drift with finite liquid release to represent an episodic fast flow arrival into the proposed repository horizon, and (3) quantify interaction and monitor fast flow paths and non-paths and non-fast pathway zones into the proposed repository horizon.

Hollins (1997a) and Mitchell (1997a) describe two small testing niches that were excavated during Fiscal Year 1997 in the west (right) rib of the TS Main Drift (which places these niches within the potential repository waste isolation standoff zone). Niche #1 was excavated at approximately Station 35+66 m. Niche #2 was excavated at approximately Station 36+50 m. The niches were excavated at a centerline azimuth of approximately 315 degrees at a 0 percent slope (within standard engineering tolerances). Thus, the centerline of the niches intersect the TS Main Drift at approximately Stations 35+69.4 m and 36+53.4 m, respectively. The niches have a minimum width of four meters and a minimum height of four meters (at the top of an arched crown). The minimum distance between the terminal face of a niche and the right rib of the TS Main Drift is about five meters.

Hollins (1997b); Mitchell (1997b) describe two additional niches were excavated during Fiscal Year 1998. Niche #3 was excavated on the right rib of the TS Main Drift near the location where the ECRB Cross Drift crosses the TS Main Drift at approximate Station 31+03.5. Niche #4 was excavated on the right rib of the TS Main Drift near Station 47+84.8 m. The final locations of Niches #3 and #4 were coordinated with the M&O's Repository Subsurface Design Department to ensure they would not interfere with the repository emplacement drift layout design (Mitchell 1997b). Niches #3 and #4 were excavated mechanically with only minor differences from Niches #1 and #2 (e.g., approximate height of the niches is approximately 3.3 m and a slight positive slope upward from the TS Main Drift was required). Consistent with previous ESF construction operations diesel-powered equipment was used to remove the muck from the excavated areas.

As described in Hollins and Mitchell (1997); Mitchell (1997b), the niches are designed to provide access to a semicircular testing zone with a radius of approximately 15 m. The testing zone consists of the niche excavation and its associated testing boreholes. Up to 10 testing boreholes were drilled for Niches #1 and #2. The boreholes varied in length from approximately 5 to 10 m. Borehole drilling (for both testing and ground support) was performed using dry-drilling techniques only, which included the use of SF_6 as a tracer gas. Three boreholes were drilled approximately one meter above the crown of Niche #1 (parallel to the planned niche excavation), and similarly, one borehole was drilled approximately one meter above the crown of Niche #2. Two boreholes per niche were also drilled within the footprint of the niche (parallel to the planned niche excavation) at the niche springline. Water, traced with LiBr and mixed with aqueous dyes, was then released into these boreholes. Similar activities with potential minor variations in the number and depth of the boreholes (i.e., 7 boreholes--approximately 10 m deep before excavation and 6 boreholes--approximately 10 m deep after construction in each niche) were performed in Niches #3 and #4.

Mitchell (1997c, 1998a) identify the proposed aqueous dyes and microspheres for release in the TS Loop niches testing activities. These dyes (which are generally categorized into two types--common food color dyes and fluorescent dyes) and microspheres are as follows:

- Federal Food, Drug, and Cosmetic Act (FD&C) Blue No. 1 (food color)
- FD&C Red No. 40 (food color)
- FD&C Yellow No. 5 (food color)
- FD&C Yellow No. 6 (food color)
- Amino G Acid
- Fluorescein (water soluble)
- Lissamine (Acid Yellow No. 7)
- Pyranine
- Rhodamine B
- Rhodamine B Sulfo
- Rhodamine WT
- Fluorescent Polystyrene Microspheres (Niches #3 and #4 only)

Mitchell (1997c, 1998a) also provided estimated maximum concentrations for each TFM. However, the PI subsequently reevaluated the Mitchell (1997c) proposed dyes for Niches #1 and #2 and the proposed concentrations, because preliminary feedback from the SA DIE team indicated that the evaluated limit (Section 11 of CRWMS M&O 1999a) for <u>committed</u> organic materials would be exceeded at these concentrations. Due to a lack of other practical, inorganic, alternative dyes, the PI subsequently revised the proposed, maximum concentration of the aqueous dyes to approximately 10 grams per liter, or about 10,000 parts per million (ppm), for all food color dyes and to approximately two grams per liter (about 2,000 ppm) for all fluorescent dyes in Niches #1 and #2 (Mitchell 1997a). These concentrations represent the minimum allowable levels necessary to achieve valid testing results (Mitchell 1997a). For Niches #3 and #4, the maximum concentrations of the aqueous dyes is approximately 10 grams per liter, or about 10,000 ppm, for all food color dyes, approximately 0.9 grams per liter (about 900 ppm) for Rhodamine B, and approximately 4 grams per liter (about 4,000 ppm) for all other fluorescent dyes (Mitchell 1998a). A total of 40 grams of Fluorescent Microspheres was also requested for use in Niches #3 and #4 (Mitchell 1998a). Mitchell (1998a) also identified two organic developers (Sodium Hypochlorite and Potato Starch) that will also be used for visually enhancing other tracer-stains on excavated rock, but will not be committed to the Subsurface ESF.

Per Hollins and Mitchell (1997), less than approximately 100 gallons of the LiBr-traced water/dye(s) mixture(s) was to be released into the testing zone of each niche. However, since the quantity of committed organic material is directly proportional to the total volume of the traced water/dye mixture, the PI also revised the proposed amount of LiBr-traced water/dye mixture to be released into these boreholes. Per Mitchell (1997a), approximately 42 liters (about 11.1 gallons) of the traced water/food color dye mixture were released into the three boreholes above Niche #1, and 84 liters (about 22.2 gallons) of the traced water/fluorescent dye mixture were released into the two boreholes at the springline of Niche #1 (for a total Niche #1 traced water/dye mixture volume of approximately 33.3 gallons). Approximately fourteen liters (about 3.7 gallons) of the traced water/food color dye mixture were to be released into the borehole above Niche #2, and fourteen liters (about 3.7 gallons) of the traced water/fluorescent dye mixture were to be released into the two boreholes at the springline of Niche #2, (for a total Niche #2 traced water/dye mixture volume of approximately 7.4 gallons). These volumes of traced water/dyes mixtures represent the minimum allowable levels necessary to achieve valid testing results, based upon the proposed dye concentrations above (Mitchell 1997a). Similar calculations can be performed for the quantities of traced water/dyes mixtures requested for Niches #3 and #4 (Mitchell 1998a). The results yield approximate volumes of dyed water in Niches #3 and #4 testing activities to be 56 liters (about 14.8 gallons) for food color dyes and 23.1 liters (about 6.1 gallons) for fluorescent dyes.

As discussed in Hollins and Mitchell (1997), some of the dye/traced water mixture released into these boreholes occurred before the niches were fully excavated. Excavation of the given niche began on a schedule as directed by the TCO. Excavation was performed using dry excavation techniques (i.e., using minimal construction water). Grab samples of muck from the niches were collected and sampled for dye infiltration. After excavation of a given niche was completed, the remaining boreholes were drilled on the inside perimeter of the exposed niche surface. The core samples were then analyzed for dye infiltration and other hydrologic characteristics.

The original plan for these tests (as described in Hollins and Mitchell 1997) also required the additional excavation of a small opening (approximately one to 1.5 m in diameter by 5 m deep) around boreholes from which core samples revealed fluid infiltration. (These openings were intended to determine the spatial distributions of the permeability, water content and dye imprints). However, the excavation of these small openings is not bounded by this evaluation. This activity will require additional evaluation, should the TCO determine that these openings are required.

Per Hollins and Mitchell (1997), no special ventilation accommodations were required for these niches, but standard power and lighting accommodations were provided. Mitchell (2000c) describes the addition of humidifiers in some niches to minimize moisture losses from the test bed. Instrumentation to monitor the niches was installed using POLYCEL Expanding Foam and the niches were sealed with bulkheads to allow the enclosed rock mass to equilibrate to ambient conditions. VERSI-FOAM has also been requested for use in sealing sections of boreholes for further niche testing. Shotcrete was placed around the perimeter of the bulkhead frames to seal them (Mitchell 1997d).

Per Mitchell (1997c, 1998a), single-hole and cross-hole gaseous tracer testing will be performed in the niches. SF_6 is the only gaseous tracer requested for Niches #1 and #2 testing. SF_6, SUVA COLD MP® (tetra fluoroethane), and noble gases (i.e., Helium, Neon, Argon, Krypton, and Xenon) are the gaseous tracers requested for Niches #3 and #4 testing. The gas tracer testing is essentially similar to the radial borehole testing described above, but on a smaller scale.

Mitchell (1998b) requested the use of new tracers in Niche #2 to quantify the extent of the wetting front from traced water introduced in the boreholes above niches. The test zones were picked to maximize the spreading of the traced water. One to two meter long boreholes will be drilled into the crown and sidewalls of the niche after the traced water is applied to provide core samples for subsequent analysis to determine the extent of the wetting area. Tracer concentrations will be monitored as part of the test. The tracers proposed for use include:

- 2,3-Diflurobenzoic Acid
- Pentafluorobenzoic Acid
- Calcium Bromide
- Calcium Iodide
- Sodium Iodide

The tracers will be released in an existing borehole located in the upper middle quadrant approximately 0.75 m above Niche #2. The traced water releases occurred in nominally one-foot intervals of the borehole isolated by packers. The total volume of water released during the tests was not to exceed 20 liters. (Mitchell 1998b)

Based on the results of this additional tracer release in Niche #2, the tracers listed in Mitchell (1998a) that were not listed above are still requested for use in Niches #3 and #4. These tracers include:

- 2,3-Diflurobenzoic Acid
- 2,4-Difluorobenzoic Acid
- 2,5-Difluorobenzoic Acid
- 2,6-Difluorobenzoic Acid
- 3,4-Difluorobenzoic Acid
- 3,5-Difluorobenzoic Acid
- 2,3,4-Trifluorobenzoic Acid
- 2,3,6-Trifluorobenzoic Acid
- 2,4,5-Trifluorobenzoic Acid
- 2,4,6-Trifluorobenzoic Acid
- 3,4,5-Trifluorobenzoic Acid
- 2,3,4,5-Tetrafluorobenzoic Acid
- 2,3,4,6-Tetrafluorobenzoic Acid
- Pentafluorobenzoic Acid
- Magnesium Fluoride
- Potassium Fluoride
- Sodium Fluoride
- Sodium Chloride
- Lithium Bromide
- Potassium Bromide
- Sodium Bromide
- Magnesium Iodide
- Potassium Iodide
- Sodium Iodide

The maximum volumes and concentrations of these tracers in Niche #3 and #4 are 350 liters (about 92.5 gallons) at a concentration of approximately 0.02 grams per liter (20 ppm) for Fluoride organics (i.e., Di, Tri, Tetra, and Pentafluorobenzoic Acids), 30 liters (about 7.9

gallons) at a concentration of approximately 5 grams per liter (5,000 ppm) for Fluoride salt compounds, 45 liters (about 11.9 gallons) at a concentration of approximately 5 grams per liter (5,000 ppm) for non-fluorinated salts (bromides, iodides, and sodium dihydrates excluding sodium chloride and LiBr), 20 liters (about 5.3 gallons) at a concentration of approximately 3 grams per liter (3,000 ppm) for sodium chloride, and 20 liters (about 5.3 gallons) at a concentration of approximately 2 grams per liter (2,000 ppm) for LiBr in excess of the 20 ± 10 ppm allowed for tracing construction water.

6.10.3 Alcove Slot Cut Testing

Mitchell (1998c, 1998d); YMP (2000c) provide a description of the alcove slot cut construction activities in ESF Alcoves #4 and #6. Mitchell (1998c) provides a generic description of the alcove slot cuts and the boreholes used to inject tracer material above the slot cuts. The two slot cuts are nominally less than five meters wide by less than five meters deep with a height of less than one-half meter. The Alcove #4 slot cut is located at the terminal (north) end of the alcove with a potential expansion of the slot cut into the last approximately one meter of the left (west) rib of the alcove. The Alcove #6 slot cut is located along the right (south) rib of the alcove beginning at approximately alcove Station 0+55 m.

Per Mitchell (1998c), the alcove slot cuts were excavated using wet or dry-drilling techniques as follows. A line of NQ-3 size pilot holes are drilled at about one-foot intervals along the planned centerline of the slot cut. A one foot diameter tri-cone reaming bit was used to drill overlapping holes using the pilot holes as guides for the reaming bit. This resulted in a roughly rectangular shaped slot (with small irregularities across the top/bottom of the slot caused by the use of a round reaming bit to create a rectangular cut). Small support jacks were inserted into the slot cut to provide support to the surrounding rock and keep the slot cut from collapsing. Boreholes were dry-drilled in a pattern determined by the PI(s) above the given slot cut in preparation for tracer testing. The boreholes extend beyond the depth of the slot cuts, but were packed off such that the releases of tracers only occur above the slot cut. Mitchell (1998e, 1998f) provided a list of the proposed TFMs, associated quantities/concentrations, and description of the methods for their injection into the boreholes above the respective alcove slot cuts. These included the following major types of TFMs:

- Fluorescent Dyes (Organics) (same as those listed for niches above)
- Food Color Dyes (Organics) (same as those listed for niches above)
- Fluorescent Microspheres (Organics) (same as listed for niches above)
- Fluorinated Organics (Di, Tri, Tetra, and Penta fluoride-substituted benzoic acids--same as listed for niches above)
- Fluorine Salts (same as listed for niches above)
- Non-Fluorine Halide Salts (same as listed for niches above)
- Non-Halide Salts (same as listed for niches above)
- Organic Developers (not to be committed to the ESF)
- Gases (same as listed for niches above)

Gas tracer testing was performed between the boreholes drilled above the alcove slot cuts. The gas tracers are listed in Mitchell (1998a, 1998e, 1998f). The gas tracer testing is essentially similar to the radial borehole testing described above, but on a smaller scale. For the liquid tracer testing, catchments and liners were used in the slot cut to collect and segregate any traced water that falls into the given slot cut.

6.10.4 Alcove Infiltration Testing

Brake (1997) describes the activities associated with the infiltration testing into Alcoves #1 and #7. Bulkheads discussed below have been installed in Alcoves #1 and #7 to seal sections of each alcove from the TS Loop. These sealed sections provide a monitoring environment conducive to water seepage into the alcove from fracture flow. The testing in Alcove #1 uses traced water applied to the surface above the alcove. The Alcove #7 testing uses only the naturally occurring water (i.e., surface precipitation). An additional infiltration test is planned between Alcove #8 in the ECRB Cross Drift and Niche #3 in the TS Loop and is discussed in Section 6.10.5 below.

For Alcove #1, instrumentation is installed in the alcove to monitor: (1) the relative humidity and temperature of the air; (2) evaporation processes on the alcove walls; (3) changes in water potential; and (4) water content in the walls and boreholes, as well as drips of water from fractures, faults, and/or rock bolts. In addition, instrumentation was placed in the rock behind applied shotcrete to simulate the effects of pre-cast or cast-in-place liners on the water movement. The instrumentation was installed in existing boreholes (including boreholes previously used for radial borehole tests) and in short (nominally less than two meter HQ-size) boreholes hand-drilled into the crown and rib(s) of the alcove. The instrumentation for Alcove #1 includes heat dissipation probes, psychrometers, temperature and relative humidity probes, pressure transducers for measuring barometric pressure, drip collection systems, and packer strings for boreholes. Neutron logging of boreholes is also performed.

Per Brake (1997), traced water (using LiBr as the tracer) was applied during the initial testing phase to the ground surface directly above Alcove #1 by intermittent application from a Polyvinyl Chloride (PVC) pipe drip irrigation system. Intermittent traced water was applied at a rate of 2 cm (0.8 inches) per day for 100 days or 1 cm (0.4 inches) per day for 200 days. The water was applied roughly equally to a 35 foot by 26 foot area (Guertal 1998). This equates to approximately 450 gallons per day for the first application rate and 225 gallons per day for the second application rate.

Mitchell (1998g) describes the use of additional tracers and traced water. This next phase of testing includes the addition of approximately 60,000 gallons of traced water. The application rate is expected to average 4 cm (1.6 inches) per day and should not exceed a maximum rate of 8 cm (3.2 inches) per day. The following tracers are used during the infiltration testing into Alcove #1:

- Lithium Bromide
- FD&C Blue No. 1 (food color)
- Fluorescein (water soluble)
- Pyranine
- Rhodamine WT
- Sodium Chloride

- Calcium Bromide
- Calcium Iodide
- Sodium Iodide
- Magnesium Fluoride

Two requests for additional water have been received. The two requests (Mitchell 1999a, 2000b) were for 60,000 gallons of traced water each. Thus, the total quantity of water requested for release above Alcove #1 is 245,000 gallons. The quantity of tracer originally requested for release with the water above Alcove #1 is still considered sufficient to complete the planned testing.

The traced water application area is covered with plastic sheeting elevated approximately one foot above the ground surface. This sheeting helps warm the area and isolates the test and its measured rate of water application from uncontrolled external influences (e.g., wind, rain). Brake (1997) also notes that the water application area is approximately 30 m (100 feet) above the Alcove #1 test area.

Alcove #1 is located at approximately Station 0+42.6 m into the ESF Starter Tunnel. CRWMS M&O (1997b) indicates that the bulkhead installed in Alcove #1 is at approximately alcove Construction Station 0+83 feet (25.3 m), which isolates the final approximately 9 m of the alcove from the ESF Starter Tunnel.

Brake (1997) and CRWMS M&O (1997b) also discuss the Alcove #7 portion of the infiltration testing. The instrumentation used in Alcove #7 includes heat dissipation probes, psychrometers, temperature and relative humidity probes, and pressure transducers for measuring barometric. In addition, a rain storage gage and heat dissipation probes were installed on the surface above Alcove #7. The above ground instrumentation is used to monitor the naturally occurring water at the ground surface above Alcove #7. No additional traced water is planned to be applied above Alcove #7.

6.10.5 ECRB Cross Drift Niches, Alcoves, and Slot Cuts

Per Scott (1998), a number of niches and alcoves were planned to be excavated off the ECRB Cross Drift. Some of these excavations include additional slot cut testing and associated boreholes between the niche/alcove and the ECRB Cross Drift. YMP (2000c) describes two of these activities that will be occurring in the near future. Specifically, a cross over alcove (Alcove #8) positioned above TS Loop Niche #3 will be excavated off the left rib of the ECRB Cross Drift (approximate ECRB Station 7+98 m) and a niche will be excavated off the left rib of the ECRB Cross Drift at approximate ECRB Station 16+20 m (Niche #5). Per Schulenburg (2000) Alcove #8 may be used as a refuge station in the event of an emergency. The refuge station will use the Alcove #8 bulkhead and including placement of necessary emergency equipment. An additional niche has been proposed at approximate ECRB Station 23+46 m (Niche #6), however, this niche is not currently funded. CRWMS M&O (2000a) provides a detailed discussion of the dimensions, orientations, and methods of construction activities required for these excavations. Descriptions of the planned testing activities and information related to the actual testing area are provided below. The excavation and construction of the ECRB niches, alcoves, and slot cuts has been allocated to CRWMS M&O (2000a).

Niche #5 is similar in design and function to the TS Loop niches with the exception that an access drift is used to separate it from main drift of the ECRB Cross Drift. Up to 18 boreholes will be installed at Niche #5 to provide access to the rock mass for monitoring and testing purposes and for the collection of rock core samples for subsequent off-site testing and evaluation. Three out of the approximately 18 boreholes were installed prior to excavating the access drift leading to the niche. Air injection tests are performed in these boreholes prior to mining out the access drift and after the niche is excavated to evaluate the effects that excavation has on rock air permeability distributions. Up to nine boreholes will be installed parallel to the niche-axis, with subsequent air injection and liquid release testing being conducted prior to and after niche construction. The end of the holes that are located outside the limits of the proposed footprint of the niche will also be tested after niche construction. Following niche construction, up to six radial boreholes will be drilled within the niche, with subsequent testing and monitoring being conducted within these holes to monitor ambient hydrologic conditions within the rock mass. (Mitchell 1999b)

A temporary testing bulkhead, similar to those used in previous niche testing will be installed using shotcrete or a similar approved sealing material for isolation of the test area. Mitchell (2000c) describes the addition of humidifiers in some niches to minimize moisture losses from the test bed. Niche #5 is located such that a second stratigraphic layer of rock will be tested. Niche #6 will be positioned in a third stratigraphic layer of rock, and if funded, is anticipated to be of similar design and function as Niche #5. Tracer concentrations will be monitored with approved and calibrated systems including, gas chromatograph mass spectrometer, fluorescence spectrophotometer, ion specific electrode ion chromatography, gas chromatography-electron capture detector, gas chromatography-thermal conductivity detector, and UV-vis spectrophotometer. The following TFMs have been proposed for use in the region of rock located in the vicinity of (primarily above) Niche #5:

- Approximately 54 liters (about 14.3 gallons) of the traced water/food color dye mixture, 4.4 liters (about 1.2 gallons) of the traced water/Rhodamine B mixture, and 27 liters (about 7.1 gallons) of the traced water/fluorescent dye mixture was requested for release into the Niche #5 boreholes (for a total Niche #5 traced water/aqueous dye mixture volume of approximately 22.6 gallons). The maximum concentrations of the aqueous dyes is approximately 10 grams per liter, or about 10,000 ppm, for all food color dyes, 0.9 grams per liter, or about 900 ppm, for Rhodamine B, and 4 grams per liter, or about 4,000 ppm, for all other fluorescent dyes.

- Approximately 350 liters (about 92.5 gallons) of the traced water/organic Fluoride compounds and 30 liters (about 7.9 gallons) of the water/Fluoride salt compounds were requested for release the Niche #5 boreholes (for a total Niche #5 water/Fluoride compound mixture volumes of approximately 100.4 gallons). The maximum concentrations of the water/Fluoride compounds is approximately 0.02 grams per liter, or about 20 ppm, for organic Fluorides and 5 grams per liter, or about 5,000 ppm, for Fluoride salts.

- Approximately 105 liters (about 27.7 gallons) of the traced water/non-fluorinated salts (bromides, iodides, and sodium dihydrates excluding sodium chloride and LiBr), 20 liters (about 5.3 gallons) of traced water/sodium chloride, and 20 liters (about 5.3 gallons) of traced water/LiBr (above 20 ± 10 ppm) was requested for release into the Niche #5 boreholes (for a total Niche #5 traced water/non-fluorinated salt mixture volume of approximately 38.3 gallons). The maximum concentrations of the non-fluorinated salts is approximately 5 grams per liter, or about 5,000 ppm, for non-fluorinated salt (excluding sodium chloride and LiBr), 3 grams per liter, or about 3,000 ppm, for sodium chloride, and 2 grams per liter, or about 2,000 ppm, for LiBr.

- Approximately 5,000 liters of the noble gases, 20 liters of Nitrogen, 20 liters of SUVA COLD MP® (tetra fluoroethane), and 1000 liters of SF_6 were requested for release into the Niche #5 boreholes. The proposed maximum concentrations of these gases are approximately .001 grams per liter, or about 1,000 ppm for the noble gases, 0.00002 grams per liter, or about 20 ppm, for Nitrogen, 0.00002 grams per liter, or about 20 ppm, for SUVA COLD MP® (tetra fluoroethane), and .001 grams per liter, or about 1,000 ppm, for SF_6.

- A total of 80 grams of Microspheres were also requested for release into the Niche #5 boreholes. Approximately 100 liters (about 26.4 gallons) of traced water is expected to be used in releasing the Microspheres into the Niche #5 boreholes.

- Two visual enhancers (Sodium Hypochlorite and Potato Starch) were also requested for use in observing other tracer-stains on excavated rock, but are not expected to be committed to the Subsurface ESF. (Mitchell 1999b)

Alcove #8 was constructed from the left rib of the ECRB Cross Drift in a manner such that it will overlie TS Loop Niche #3. The alcove is approximately one meter wider than Niche #3 with roughly one-half meter extension beyond each rib of Niche #3. The alcove's length is such that it will overlie a small portion of the TS Main Drift just outside of Niche #3 (approximately one meter beyond the right rib of the TS Main Drift). This extension beyond the Niche #3 test area will facilitate a preliminary test to be conducted in the back of Alcove #8 to ensure that an adequate recovery of water is demonstrated (Mitchell 2000a). The preliminary test will consist of two phases. The first phase will use a small disk infiltrometer to introduce a small quantity of traced water to characterize the rock and fracture system. The second phase will be a small scale test, approximately one meter by one meter, similar to the main test planned in Alcove #8. Mitchell (2000d) describes a proposed expansion of the small scale test to include a trench (nominally 15 cm deep by 40 cm wide) along a fault near the one meter by one meter test area. The trench would be separated into smaller segments using small dividers made out of grout. A removable steel or plastic plate would be used to cover the trench to avoid tripping hazards and minimize adverse evaporation. This expansion of the small scale test is expected to speed the water recovery process and increase the probability of locating any fast pathways between Alcove #8 and Niche #3. Traced water will be introduced into the small scale test bed and recovered below in the TS Main Drift, directly in front of Niche #3, and/or within Niche #3. An air block will be installed just ahead of the expected recovery location in the TS Main Drift to minimize the impacts of ventilation on the recovery effort. An additional small scale test has been performed on the bulkhead side of the main Alcove #8 test area. Preliminary results of this testing are provided in Section 11.1.5. The main test in Alcove #8 combines passive and active testing program to monitor and measure induced seepage into Niche #3 and includes an approximate three meters by four meter water introduction area filled with a substance such as "Overton" type sand to distribute the water evenly. A painted metal frame approximately 30 cm high will divide the test bed into 1 m square sections and will be grouted into place on the invert of Alcove #8. A small kerf, approximately 1 to 2 inches wide by 0.5 inches deep, may be excavated in the invert to install the metal frame. Additional leveling of the alcove invert may be required to optimize the test bed. Up to 10 concrete slabs, approximately 1 m by 1 m, will be installed in Alcove #8 to support the precise load cells required to monitor the weight loss of the liquid tracers. (Mitchell 2000a)

Neutron logs, heat dissipation probes, time domain reflectometry, tensiometers, and other instrumentation will be used to monitor the induced seepage from Alcove #8 into Niche #3. In addition, ground penetrating radar is planned to be used to monitor the wetting front between Alcove #8 and Niche #3. In order to use these penetrating radar techniques, one nominally three-inch diameter borehole will be drilled between Alcove #8 and the Niche #3 area (Mitchell 2000a). This borehole facilitates the time sensitive signal transfer between the two locations during the penetrating radar tests. The borehole will be elevated approximately 0.75 m above the invert in Alcove #8 so as to minimize the potential for liquid transfers directly between the two excavations.

The installation of "cut-outs" on the three perimeter sides of Niche #3 has been proposed to enhance the ability to monitor and collect water passing around the excavated opening of the niche. The "cut-outs" would consist of slots cut into the two ribs and terminal end of Niche #3, approximately 0.75 m above the invert. The "cut-outs" would be angled slightly upward and be approximately 1 to 1.5 m deep. Similar "cut-outs" have been proposed for Niche #5, but they would be excavated approximately 2.5 m above the invert. (Mitchell 2000a)

As much as 100,000 gallons of traced water has been proposed for introduction into Alcove #8 with a collection system in Niche #3. Rates of water application are planned to be between 10 to 100 gallons/hour using a calibrated flow meter. In addition, a temporary testing bulkhead has been installed to isolate the water distribution system in Alcove #8. This bulkhead is similar to other niche/alcove bulkheads and has been sealed using shotcrete or a similar approved material. The following tracers (with quantities and concentrations) have been proposed for application into the Alcove #8 water distribution system: (Mitchell 1999c)

- Lithium Bromide (140 Kilograms [kg] at 600 ppm)
- Fluorescein (water soluble) (0.2 kg at 1 ppm)
- Pyranine (0.2 kg at 1 ppm)
- Rhodamine WT (0.2 kg at 1 ppm)
- Sodium Chloride (550 kg at 2,000 ppm)
- Calcium Bromide (140 kg at 500 ppm)
- Calcium Iodide (2 kg at 10 ppm)
- Sodium Iodide (2 kg at 10 ppm)
- Magnesium Fluoride (20 kg at 87 ppm)

Three of the proposed tracers listed above that have not been approved for use are, magnesium fluoride, sodium chloride, and calcium bromide.

Additional proposed tracers lactic acid sodium salt and methane gas in air have been requested for the Alcove #8/Niche #3 testing and approved (Parsons 2001a, 2001b). Up to 150,000 gallons of water (Mitchell 2001) has been proposed to inject with the following tracers into Alcove #8 test-beds:

Tracer	Total quantity	concentration
Lithium Bromide	1,000 gram	500 ppm
Calcium Chloride	2,000 gram	2,000 ppm
Potassium Fluoride	100 gram	50 ppm
Potassium Iodide	50 gram	10 ppm
2,3-Difluorobenzoic Acid	50 gram	50 ppm
2,4-Difluorobenzioc Acid	50 gram	50 ppm
2,5-Difluorobenzoic Acid	50 gram	50 ppm
2,6-Difluorobenzoic Acid	50 gram	50 ppm
3,4-Difluorobenzioc Acid	50 gram	50 ppm
3,5-Difluorobenzoic Acid	50 gram	50 ppm
2,3,4-Trifluorobenzoic Acid	50 gram	50 ppm
2,3,6-Trifluorobenzoic Acid	50 gram	50 ppm
2,4,5-Trifluorobenzoic Acid	50 gram	50 ppm
2,4,6-Trifluorobenzic Acid	50 gram	50 ppm
3,4,5-Trifluorobenzic Acid	50 gram	50 ppm
2,3,4,5-Tetrafluorobenzoic Acid	50 gram	50 ppm
Pentafluorobenzoic Acid	50 gram	50 ppm
FD&C Blue No. 1	20 gram	20 ppm
Sulpho Rhodamine B	10 gram	10 ppm
Fluorescein	10 gram	10 ppm
Pyranine	10 gram	10 ppm
Rhodamine WT	10 gram	10 ppm
Lactic Acid Sodium Salt	30 gram	100 ppm
Methane gas in air	20 liters	40,000 ppm
Fluorescent Microspheres	1 Liter	

Additional testing may include a second niche (as discussed above), alcove(s)/drilling for evaluation of the Solitario Canyon fault, and a small-scale thermal test above the repository. The second niche would be used for fracture mechanics studies similar to the TS Loop niches and ECRB Niche #5. A crest alcove (Alcove 9) (positioned in one of the higher anticipated natural infiltration areas of the proposed repository) with bulkheads and monitoring instrumentation similar to that used in alcove infiltration testing was proposed, but the installation of the two bulkheads within the ECRB Cross Drift will likely supplant this testing activity. Slot cut testing may be included that is similar to TS Loop alcove slot cut testing, but on a larger scale. The extension of planned and/or existing boreholes, up to 30 m in length, for the installation of temperature monitoring equipment was also discussed. The testing activities associated with these excavations will be evaluated in a future revision to this DIE or another DIE. (Scott 1998)

Alcove 10 may conduct testing using cross-drift thermal studies. The purpose of these field thermal tests is to better understand the heat-driven coupled processes in the nearfield rock in the potential repository. (YMP 2001)

6.10.6 Chlorine-36 Monitoring and Testing

Chlorine-36 testing is conducted to obtain information about rates and potential pathways for water movement in the UZ at Yucca Mountain. Chlorine-36 testing primarily consists of core and rock sample analysis. Samples are collected at various locations to include likely transmissive features such as faults, fractures, and breccia zones (Levy et al. 1997). Samples are primarily taken from boreholes drilled for other functions (e.g., radial boreholes, moisture study holes). The samples are processed in the laboratory to determine Chlorine-36 levels. This testing activity is one used to estimate aqueous pathways and travel times from the ground surface to the Subsurface ESF. Additional short boreholes (nominally less than two meters long) and hand-chipped sample blocks (nominally one cubic foot) are excavated at selected locations, as designated by the TCO, for further studies of potential fast pathways in the ESF. No TFMs are emplaced in the Subsurface ESF during Chlorine-36 testing.

As part of the validation efforts associated with earlier Chlorine-36 testing, short, HQ boreholes (nominally 3 to 4 m long) may be dry-drilled near locations in the Subsurface ESF where elevated levels of Chlorine-36 have been detected. Peterman (1998) describes one such validation effort near the Drill Hole Wash and Sundance Fault structures. Mitchell (1999d) describes approximately 10 and 40 boreholes, respectively, drilled off the TS Loop near the areas where it contacts these geologic structures. A few of these boreholes may be up to 10 m deep to facilitate monitoring for potential interactions between the Chlorine-36 boreholes and testing/construction activities. The boreholes are drilled nominally horizontal (±12 degrees of horizontal) at a height of approximately 1.5 m above the invert. All the boreholes are planned to be drilled off the right rib of the TS Loop. The cores from these boreholes are packaged for off-site processing.

6.11 TESTING IN THE TS MAIN DRIFT THERMAL TESTING FACILITY

The TTF is located off the left rib of the TS Main Drift at approximately Station 28+27 m. The TTF is an alcove (Alcove #5) designated for a series of tests as describe below. FWP-ESF-96-003 (YMP 1997d) provides a description of the activities associated with "Thermal Testing in the ESF - Phase I." The TTF was excavated using a combination of drill-and-blast and mechanical mining using a Road Header (Alpine Miner). CRWMS M&O (1999a) evaluated the construction activities associated the TTF.

6.11.1 Thermomechanical Alcove

The TMA (previously identified as the Shakedown Test Area) is a section of the TTF located off the right rib of the Access/Observation Drift (AOD) at approximately alcove Station 0+38.5 m. The TMA and TMA Extension were used to conduct an instrumentation shakedown using a small scale single heater test. Per YMP (1997d), the single heater test objectives were to: (1) provide measurements to examine rock-mass thermal properties; (2) measure changes in rock saturation before, during, and after heating; (3) measure the thermal expansion of the rock mass; (4) investigate the propagation of a drying front and subsequent re-wetting; (5) measure residual saturation levels in the dry zone; (6) examine the validity of conductive thermal models; (7) observe occurrences of liquid reflux in fractures; (8) measure changes in rock-mass and fracture permeability; (9) determine changes in the chemistry of reflux water; (10) measure rock-mass modulus under thermal conditions; (11) evaluate rock-mass strength; (12) observe ground support interactions; and (13) expand an *in situ* test and instrumentation experience base. The TMA/single heater test stage of the Phase I thermal testing is comprised of the following activities:

- Geologic reconnaissance of the structure features in the walls and ceiling of the tunnels. The geologic reconnaissance included the evaluation of fractures, altered zones, and seeps, if observed. Rock quality mapping was carried out to assess the stability of the test bed and to assist in the selection of the location for heater placement.

- The drilling of numerous testing-related boreholes into the pillar between the AOD and the TMA Extension. These boreholes originate from the TMA, AOD, and TMA Extension. While dry drilling of these boreholes was preferred (CRWMS M&O 1996b), drilling with water was allowed due to the realization of significant cost savings. Core samples were collected for laboratory evaluation.

- The performance of pre-test characterization activities in these boreholes, including borehole logging for pressure, temperature, and moisture content; borehole scanning to obtain a visual description of the rock matrix and fractures; and air injection and interference pumping tests to determine permeability.

- The installation of an approximately five-meter long heater assembly and associated instrumentation into the borehole designated for this purpose.

- The installation of a diverse array of instrumentation into designated boreholes, including instrumentation to measure temperature, relative humidity, gas/air pressure, liquid water saturation levels, geochemistry, and mechanical properties. High-temperature grouting material was used in some of these installations; others used high-temperature packers. Geochemical measurement boreholes were equipped with "SEAMIST" (Science Engineering Associates Membrane *In situ* Sampling Technique) or similar assemblies. Boreholes designated for neutron logging (i.e., one of the methods to be used to measure water saturation levels) were fitted with a Teflon tube liner.

- The installation of four instrumented rockbolts into designated holes near the heater assembly.

- The installation of a DCS for data acquisition and recording purposes.

- The conduct of an M&O management-directed preparedness assessment before heater energization.

- The energization of the heater assembly for approximately nine months. The heater was designed such that rock-mass temperatures at minimum radial distance of one meter from the heater exceeded 100 degrees Celsius, with rock-mass temperatures in excess of 200 degrees Celsius adjacent to the heater.

- A cool-down monitoring period of approximately seven months.

- Post characterization activities to include removal of insulation and selected instruments, video logging, air injection testing, Goodman jack testing, pull testing and possible overcoring of rockbolts, dry-coring of new boreholes, and overcoring of various existing boreholes for scientific purposes. (Weaver 1997)

6.11.2 Sequential Drift Mining Studies

Before construction of the Heated Drift, instrumentation was emplaced in the rock mass adjacent to the location of the Heated Drift. These boreholes emanated from the AOD and allowed for excavation investigations referred to as sequential drift mining studies. Per YMP (1997d), the test objectives were to provide measurements to: (1) examine the extent and behavior of the stress-altered region around a newly excavated opening before, during, and after heating; (2) observe and evaluate rock-mass/ground support interactions; (3) provide baseline information for the evaluation of mechanical aspects of Thermal/Mechanical/ Hydrological/Chemical (TMHC) coupling; and (4) evaluate thermomechanical models used to predict rock-mass behavior.

6.11.3 Plate-Loading Testing

The plate-loading test activity is located in the TTF just outside the Heated Drift. Per YMP (1997d), the objectives of the plate-loading testing are to: (1) measure the thermal expansion of the rock mass, (2) measure the rock-mass modulus at elevated temperatures, (3) provide baseline information for the evaluation of mechanical aspects of TMHC coupling, and (4) evaluate thermomechanical models used to predict rock-mass behavior.

6.11.4 Heated Drift Testing

The ESF TTF Heated Drift is located at the end of the TTF parallel to, but offset laterally by approximately 32 m from the AOD. The ESF TTF Heated Drift is the site of the Drift Scale Test (DST). Per YMP (1997d), the DST objectives are to provide measurements to: (1) examine the coupled TMHC processes that may impact potential waste packages; (2) produce *in situ* data on the effect of heat on spatial and temporal distributions of temperature, moisture content, water chemistry, and displacement of rock mass; (3) compare the measured data with model predictions so that coupled process models can be tested; (4) provide a conceptual model and hypothesis test bed for heat transfer mechanisms, heat pipes, buoyant phase, convection condensate refluxing, and binary diffusion; (5) measure corrosion rates on typical waste package materials under *in situ* conditions; (6) evaluate the effect of introduced materials on the near-field environments; (7) evaluate the effect of ground support interactions with the heated rock mass, including the effect of materials used for ground support on the near-field water chemistry; and (8) provide detailed measurements of the response of the rock mass to the construction and heating of an emplacement size drift.

The closest potential waste package emplacement area to the Heated Drift is the Primary Waste Emplacement (WE) Area, which is located just west of the ESF TS Main Drift (CRWMS M&O 1994a, 1997c). The offset distance between the western rib of the ESF TS Main Drift and the Heated Drift is approximately 77 m (CRWMS M&O 1997c). As noted in CRWMS M&O (1995a), the nearest potential waste package emplacement to the west of the ESF TS Main Drift must be offset by a minimum distance of 37 m, so the minimum offset distance between a potential emplaced waste package and the Heated Drift is approximately 114 m.

Brake (1996) provides an overview of DST activities. YMP (1997d) includes a table (termed the *Administrative Borehole Layout Table*) that identifies the test boreholes drilled in the proximity of the TTF Heated Drift. These boreholes are designated "Drift-Scale Test" in the fourth column of the table. YMP (1997d) also provides a plan view of these boreholes. Approximately 100 boreholes emanate from the TTF Heated Drift itself, with approximately half of these used to situate wing heaters. The other boreholes emanating from the Heated Drift house instrumentation for monitoring temperature, thermal conductivity and diffusivity, rock mass displacement (using MPBXs), and rock water content (using electrical resistivity tomography [ERT]). Other boreholes, outfitted with similar instrumentation, emanate from the Connecting Drift and the AOD. The Administrative Borehole Layout Table (YMP 1997d) indicates that all but three of the boreholes were drilled with traced construction water as the drilling fluid. The three exceptions are "Ambient Characterization" boreholes (borehole numbers 182, 183, and 184) that are designated "dry cored" in the table.

Brake (1996) also identifies various TFMs planned to be used for the Heated Drift testing. This DIE evaluates these TFMs based on their similarity to TFMs that have been previously evaluated in CRWMS M&O (1999a).

Other DST temporary testing accommodations and activities are described as follows:

- The installation of a cast-in-place concrete liner between Stations 00+48.4 and 00+60.75 m (i.e., approximately 12.5 m) of the Heated Drift (CRWMS M&O 1997d, 1997e). The liner is a temporary test component of the DST and was not designed to provide ground support for the Heated Drift. Rather, the liner is being tested to establish the qualitative performance of concrete in a simulated repository environment (CRWMS M&O 1997f).

- The minimum outer diameter of the liner (i.e., the diameter of the excavated opening) is approximately 5.6 m. The inner diameter of the liner (i.e., the exposed surface inside the

Heated Drift) is nominally 5.2 m. The minimum wall thickness of the liner is 0.2 m (CRWMS M&O 1997d, 1997e).

- The installation of a cast-in-place concrete invert floor for the entire circular portion of the Heated Drift (approximately 47.5 m in length) (CRWMS M&O 1997c; Weaver 1996a). The invert floor is approximately 1.2 m high (as measured along the center line from the tunnel floor to the top of the concrete invert) (Weaver 1996a). The invert floor serves only as a test support accommodation (i.e., a level floor surface for the Heated Drift). However, the invert floor directly interfaces with a Heated Drift testing component, in that the invert floor is also placed within the cast-in-place concrete liner section of the Heated Drift (Weaver 1996a). Due to this testing interface, the cast-in-place concrete invert floor is being evaluated herein, in lieu of being evaluated in CRWMS M&O (1999a).

  In addition to the Heated Drift concrete invert floor, there are five other temporary, cast-in-place concrete applications (i.e., associated with flooring requirements) for the DST. Per Weaver (1996a), four of these applications include a ramp from the elevation of the Connecting Drift floor to the Heated Drift invert floor elevation, a thin floor for the DST Drilling Bay, a thin floor for the short equipment niches, and a load retaining frame (consisting of approximately 11 cubic yards of concrete) for the Plate Loading Niche (which is located on the right rib of the Heated Drift outside the bulkhead near the Connecting Drift). A cast-in-place concrete floor is needed for the entire AOD. Per Morrison (1998), approximately 203 cubic yards of light-weight insulating concrete are needed between the Connecting Drift and the TMA. Approximately 20 to 30 cubic yards of regular concrete are needed between the TMA and the TS Main Drift (Morrison 1998).

- The conduct of pre-test characterization activities in DST boreholes, which includes borehole: (1) logging for pressure, temperature, and moisture content; (2) borehole scanning to obtain a visual description of the rock matrix and fractures; and (3) air injection and interference pumping tests to determine permeability (CRWMS M&O 1996b).

- The installation of heater assemblies. Wing heaters are emplaced in horizontal boreholes along the full length of the Heated Drift at approximately 0.25 m below the springline (CRWMS M&O 1996b). Heaters mounted in canisters are emplaced on the concrete invert floor (CRWMS M&O 1996b).

- The installation of a DCS for data acquisition and recording purposes (CRWMS M&O 1996b).

- The installation of a bulkhead which physically separates the Heated Drift from the rest of the TTF during the conduct of the DST (CRWMS M&O 1996b). The bulkhead does not provide an air-tight seal, rather it is equipped with several penetrations to facilitate instrumentation and power cable passage. The bulkhead is also equipped with cable supports (on the Heated Drift side of the bulkhead) to control cable bend radii, temperature measuring devices, lighting for the Heated Drift side of the bulkhead, two viewing ports for visual inspection of the Heated Drift, and a controlled-access door for testing-support by personnel and a small hand-held equipment access (Hollins 1996).

- The erection of cable trays in the Connecting Drift and Heated Drift; a pre-fabricated building (with air conditioning, power, and lighting accommodations) at the end of the AOD and a test frame in the Plate Loading Niche (YMP 1997d).

- The installation of a designed fire suppression system in the office at the end of the AOD that uses FM-200® "clean agent" as a fire suppression agent (Logan 1997).

- The installation of heater power monitor boxes on the ribs of the Connecting Drift; connection of heater wires to the power monitor boxes; transportation and positioning heater canisters on the invert of the Heated Drift; grouting of instrumentation in boreholes; and sealing of boreholes by applying grout or other mechanisms to the borehole circumferences (YMP 1997d).

- The installation of fiberglass insulation along the exposed surfaces of the AOD, Connecting Drift, and Heated Drift where required to provide protection from the heated rock. An aluminum sheet lagging will be used over the insulation for protection of personnel and the insulation itself. (CRWMS M&O 1998a).

- The initiation of the test by energizing all floor and wing heater assemblies for up to four years. The heater assemblies increase the temperature of the Heated Drift rock walls to approximately 200 degrees Celsius at the end of a two year heating period. If the heating period extends to 4 years, the peak rock wall temperature expected in the Heated Drift is approximately 270 degrees Celsius (CRWMS M&O 1996b).

- A cool-down monitoring period which is expected to be comparable in duration to that of the heating period (although less time may be required for the Heated Drift to cool to ambient temperature). The power to the heaters will be ramped down at the conclusion of a constant heating phase as part of a controlled cooling period (CRWMS M&O 1996b).

- Post characterization activities to include removal of insulation, bulkheads, and selected instruments and test components; geophysical logging; permeability testing; mechanical testing such as plate loading, Goodman jack testing, pull testing and/or overcoring of rockbolts; coring of new boreholes; and possible overcoring of various existing boreholes for scientific purposes (Weaver 1999a).

6.12 HYDRAULIC FRACTURE TESTING

Hydraulic fracture testing involves the drilling of a nominally 30-m deep (100-foot) borehole nominally vertically downward and is described in Ricketts (1996). The controlling FWP is FWP-ESF-96-002 (YMP 1999b). Core samples are taken during drilling to determine the best locations in the borehole to perform the tests. Straddle-packer elements (water-inflatable packing bladders) are inserted above and below the zone to be fractured. The straddle-packer elements are pressurized, and then the test area in between (nominally less than two feet long) is pressurized with water until a fracture occurs. The test pump is shut off shortly after the fracture occurs, and the shut-in and decaying water pressures are monitored. This pressurization/depressurization cycle is repeated several times for additional data collection. Water flow-back quantities are recorded for each of the multiple pressurization/depressurization cycles.

Upon completion of data collection, the straddle-packer elements are depressurized and the test area is shifted to a new location in the borehole (generally several feet away from preceding test locations). Ricketts (1996) indicates that approximately five gallons of water are used at each location. The test is usually performed at approximately five locations in the borehole.

The final step in the hydraulic fracture testing is to perform a fracture impression-orientation test. In this portion of the test, impression packers are lowered to the locations of previously induced fractures and pressurized. The orientation of the impression packer is recorded before depressurization. The orientation and resulting hydraulic imprint on the impression packer are recorded on a transparent sheet.

Hydraulic fracture testing was conducted in the Alcove #5 and #6 Turn-Around Bays and at the end of the TTF AOD. An additional proposed site was in the TMA, but testing at this site is currently not scheduled. Hydraulic fracture testing has also been proposed at locations in the ECRB Cross Drift, but will be evaluated in a future revision to this DIE or another DIE. Other than traced water, no TFMs are lost during these tests.

6.13 GEOMECHANICS OF ROCK MASS STUDIES

6.13.1 Goodman Jack Testing

Subsurface geomechanics of rock mass studies (also known as Goodman Jack testing) includes the wet-drilling and sampling of NX-size boreholes as described in CRWMS M&O (1997b) and Lee (1997). The controlling FWP is FWP-ESF-96-002 (YMP 1999b). These boreholes are nominally 7.5 m in length and are used to perform geomechanics of rock mass studies to assist in the determination of geomechanical stability of the proposed repository rock. The boreholes are typically drilled in pairs, one horizontal and one vertical, to provide deformability data for all three dimensions. In selected locations the vertical downward boreholes are drilled to approximately 30 m in length to accommodate hydraulic fracture testing, as discussed above. Per Lee (1997), present testing locations include the Alcove #5, #6, and #7 Turn-Around Bays. (Additional boreholes and locations could be added if funding becomes available.)

Goodman jack testing involves deploying a 76-millimeter (mm) (3-inch) borehole jack which applies unidirectional pressure to the borehole wall by means of two opposed curved steel pistons, each covering a ninety degree sector over a length of approximately 20 cm (Lee 1997). Testing is performed in accordance with ASTM D4971.

6.13.2 Geotechnical Rock Properties Testing

Cored boreholes and slot cuts are being constructed in the TS Loop and the ECRB off the main tunnels to allow testing of geomechanical rock properties both in the underground environment and in the laboratory using cored materials (Weaver 2001b).

6.14 ECRB CROSS DRIFT TESTING

As discussed in Mitchell (1997e); Scott (1998), the following testing activities are conducted in the ECRB Cross Drift. Generally, testing activities conducted within the ECRB Cross Drift consist of dry drilling (using rock bolt drills), dry coring, air monitoring, bulk rock sampling techniques. ECRB Cross Drift testing also includes niche and alcove studies discussed in Section 6.10 above. The general testing activities are described in further detail in the other sections of this document and YMP (1997b, 1999b, 2000a, 2000b, 2000c). Ventilation system tests (e.g., simulated smoke or gas releases) may be performed to ensure system integrity or for validating emergency procedures. The following sections provide a general description of currently planned ECRB Cross Drift testing activities (other than ECRB niches and alcoves).

6.14.1 ECRB Cross Drift Moisture Studies

The major emphases of moisture studies in the ECRB Cross Drift are hydrologic testing and hazardous mineral (i.e., minerals having the potential to adversely impact waste isolation capabilities) assessment. The general activities associated with moisture flux studies are described in Section 6.10 and YMP (1999b, 2000c). Moisture Flux Studies were performed in Phase I of the ECRB cross drift. These tests also generated data used for confirming that the Phase II evaluation of potential waste isolation impacts herein, associated with water and organic material loss, are sufficient to bound Phase II ECRB Cross Drift activities. The ECRB systematic drill activities described in Mitchell (1999e) and YMP (2000c) will provide data on the hydrologic properties of the proposed repository rock. The following specific ECRB Cross Drift testing activities are planned in specified sections of the ECRB Cross Drift.

1. After TBM operation commenced, a single approximately 1.5-inch diameter by 2-m deep dry-drilled hole using one of the TBM-mounted rock drills was drilled about every 25 m of excavation of the ECRB Cross Drift. These boreholes were drilled into the left rib of the drift at a height accessible from the invert. An instrument package (heat dissipation probe) was placed in each of these boreholes by the PI as quickly as practical after the cutterhead exposes the rock matrix. This testing activity was conducted throughout the TBM-excavated portion of the ECRB Cross Drift.

2. After TBM operation commenced, a single HQ-sized by about 2-m deep dry-drilled/cored borehole was drilled at approximately 50-m intervals of the drift excavation. These boreholes were drilled/cored into the left rib of the drift at a height accessible from the invert using a core rig. Neutron logging is conducted in these boreholes at predetermined time intervals. This testing activity is throughout the TBM-excavated portion of the ECRB Cross Drift.

3. After TBM operation commenced, a single HQ-sized by about 6-m deep dry-drilled/cored borehole was drilled at approximately Station 5+00 m of the ECRB Cross Drift excavation. This borehole was also drilled/cored into the left rib of the drift at a height accessible from the invert using a core rig. Neutron logging is conducted in these boreholes at predetermined time intervals. This testing activity is conducted throughout the TBM-excavated portion of the ECRB Cross Drift beginning at approximately Station 10+00 and at approximately 500-m intervals thereafter.

4. Beginning at approximately Station 2+38 m, an approximate 50-m test area was established in which the constructor used water at an application rate that was calculated based on both machine optimization and dust abatement requirements. In this test area, three HQ-sized boreholes were dry drilled/cored in an array from a core rig mounted on a flat car. These boreholes were arranged such that one borehole was drilled/cored in each of the following configurations: (1) approximately 2 m deep into the left rib below springline, (2) approximately 6 m deep into the left rib above the invert, and (3) approximately 10 m deep into the bottom of the invert. These boreholes were drilled/cored immediately after the TBM trailing gear had passed. About one week later, a 15-m HQ-sized dry-drilled/cored borehole was drilled/cored into the bottom of the invert in the same array. Cores were collected, and neutron logging is conducted in these boreholes at predetermined time intervals. The primary testing activity for these boreholes is discussed and evaluated in CRWMS M&O (2000a) and is not evaluated in this DIE. However, ongoing moisture studies conducted in these boreholes are evaluated by this DIE.

5. Beginning at approximately Station 2+88 m, an approximate 50-m test area was established in which the constructor used an approved organic surfactant during TBM operations. In this "test area," three HQ-sized boreholes were dry drilled/cored in an array from a core rig mounted on a flat car or on the TBM. These boreholes were arranged such that one borehole was drilled/cored in each of the following configurations: (1) approximately 2 m deep into the left rib below springline, (2) approximately 6 m deep into the left rib above the invert, and (3) approximately 10 m deep into the bottom of the invert. These boreholes were drilled/cored immediately after the TBM trailing gear had passed. About one week later, a single 15-m HQ-sized dry-drilled/cored borehole was drilled/cored into the bottom of the invert in the same array. Cores were collected, and neutron logging is conducted in these boreholes at predetermined time intervals. The primary testing activity for these boreholes is discussed and evaluated in CRWMS M&O (2000a) and is not evaluated in this DIE. However, ongoing moisture studies conducted in these boreholes are evaluated by this DIE.

6. Small drainage bench tests are planned throughout the ECRB Cross Drift. YMP (2000c) describes a series of these drainage bench tests that involve the excavation of approximately 1-m long by 1-m wide by 0.5-m high openings on the left rib or the ECRB Cross Drift. The amount of LiBr traced construction water is to be minimized during construction of these openings. These small openings allow for

testing with nominally 24-inch diameter infiltration rings where controlled quantities of traced water will be applied. Per YMP (2000c), the TCO will provide appropriate signage and protection to ensure the tests are properly protected. Furthermore, the final bench locations are coordinated between the PI(s) and TCO so as to ensure negligible test interference.

7. Systematic hydrologic characterization testing is planned throughout sections of the ECRB Cross Drift. These tests are designed to measure the seepage potential, address the impact of spatial variability of fracture flow and transport properties, as well as the influence of mechanical deformation due to drift openings seepage and drainage. One such test (between approximate ECRB Stations 14+44 m and 17+63 m) is described in Mitchell (1999e) and YMP (2000c) and involves the drilling and testing of approximately 19 HQ-3 size, 20-m long boreholes. Approximately 6 of these boreholes will be drilled in horizontal pairs, about 2 to 3 m apart, at approximate 90-m intervals off the rib of the ECRB Cross Drift. Cross hole air-injection testing using SF_6 and selected noble gases (i.e., Krypton, Neon, and Xenon) for fracture flow connectivity and gas tracer testing for effective fracture porosity are planned in each borehole pair. Approximately 3 near vertical boreholes at approximate 90-m intervals off the crown of the ECRB Cross Drift are planned for packed interval air permeability testing. The remaining boreholes (approximately 10) will be drilled approximately 15 degrees (upward) off horizontal and aligned with the ECRB Cross Drift. These boreholes will be collared on the ECRB Cross Drift crown and dry-drilled such that the boreholes will be a few meters above the ECRB Cross Drift crown at their terminus.

   Borehole scanning, air permeability test, and pulse liquid releases have been proposed for these boreholes. Per Mitchell (1999e), the test equipment planned to be used for this activity includes: mass flow controllers; pressure transducers; tracer handling, air, or liquid injection/release systems; sample collection systems; mass spectrometer(s); and data collection and management systems (which are planned to be connected to the fiber optic system currently in the Subsurface ESF).

   Per Mitchell (1999e), the pulse liquid tracer testing would involve the release of traced water (using approved tracers) in four to five packed-off sections of the slanted boreholes. The crown of the ECRB Cross Drift will be monitored for seepage. The following tracers have been requested for release during the ECRB Systematic Drilling activity:

   - FD&C Blue No. 1 (food color)
   - FD&C Red No. 40 (food color)
   - FD&C Yellow No. 5 (food color)
   - FD&C Yellow No. 6 (food color)
   - Amino G Acid
   - Fluorescein
   - Lissamine (Acid Yellow No. 7)
   - Pyranine

- Rhodamine B Sulfo
- 2,3-Diflurobenzoic Acid
- 2,4-Difluorobenzoic Acid
- 2,5-Difluorobenzoic Acid
- 2,6-Difluorobenzoic Acid
- 3,4-Difluorobenzoic Acid
- 3,5-Difluorobenzoic Acid
- 2,3,4-Trifluorobenzoic Acid
- 2,3,6-Trifluorobenzoic Acid
- 2,4,5-Trifluorobenzoic Acid
- 2,4,6-Trifluorobenzoic Acid
- 2,3,4,5-Tetrafluorobenzoic Acid
- 2,3,4,6-Tetrafluorobenzoic Acid
- Pentafluorobenzoic Acid
- Sodium Chloride
- Lithium Bromide
- Sodium Iodide

The maximum volumes and concentrations of these tracers requested for release in the ECRB Systematic Drill activity are 25,000 liters (about 6,605 gallons) at a concentration up to approximately 0.0004 grams per liter (0.4 ppm) for fluorescent dyes, 20,000 liters (about 5,284 gallons) at a concentration up to approximately 0.02 grams per liter (20 ppm) for food color dyes, 65,000 liters (about 17,173 gallons) at a concentration of approximately 0.02 grams per liter (20 ppm) for Fluoride organics (i.e., Di, Tri, Tetra, and Pentafluorobenoic Acids), 5,000 liters (about 1,321 gallons) at a concentration of approximately 0.005 grams per liter (5 ppm) for sodium iodide, 5,000 liters (about 1,321 gallons) at a concentration of approximately 0.4 grams per liter (400 ppm) for sodium chloride, and 5,025 liters (about 1,328 gallons) at a concentration of approximately 1 grams per liter (1,000 ppm) for LiBr in excess of the 20 ± 10 ppm allowed for tracing construction water.

8. Thermal conductivity measurements may be conducted in the ECRB Cross Drift. Multiple boreholes, 10 to 15 m deep, would be dry-drilled from the left rib approximately one meter or greater above the invert from ECRB Stations 14+40 to 17+63 m. Future drilling may extend beyond Station 17+63 m. (Weaver 2001a)

9. Throughout ECRB Cross Drift construction activities, construction support will be requested by the TCO to install simple hangers for testing instrumentation including temperature, humidity, and air monitoring stations. Periodically, the TCO may request that the conveyor belt be stopped temporarily to collect muck samples.

6.14.2 Other ECRB Cross Drift Testing

Construction monitoring, consolidated sampling, perched water testing, geologic mapping, and other systematic testing are conducted where applicable in the ECRB Cross Drift. These activities are described in the other sections of this DIE and are sufficiently similar to that testing such that they may be evaluated together. Therefore, other than those ECRB Cross Drift tests specifically evaluated separately (i.e., niches, alcoves, and moisture studies), there are no other planned ECRB Cross Drift testing activities that require evaluation.

In addition to testing described above, testing referenced in Weaver (1999b) will be conducted near the proposed opening of Niche #5 in the ECRB Cross Drift to determine the effects of drill-and-blast excavation on air-permeability measurements. Three approximately 20 m long, dry cored, horizontal boreholes will be excavated in the left rib of the ECRB Cross Drift near the perimeter of the breakout for Niche #5 (approximate ECRB Station 16+20 m). These boreholes will be used for air-permeability measurements and blast effects monitoring both before and after the excavation of ECRB Niche #5. Similar testing may be performed in the vicinity of Alcove #8 and/or Niche #6. No TFMs other than approved gases are planned to be permanently emplaced for these tests.

6.14.3 Cross Drift Thermal Testing (CDTT-Alcove 10)

This testing is focused on the Topopah Spring lower lithophysal (Tptpll) unit with the primary objective of observing how the liquid water from the condensation of rock pore-water vaporized by heat, travels through the rock, and whether liquid water can penetrate through a volume of rock heated to above 100^0C. Observations in the CDTT on the movement of heat-driven water in Tptpll are expected to confirm the premise that water mobilized by the decay heat from the emplaced waste will drain by gravity through the cooler central regions of the pillar between the drifts to below the emplacement horizon.

A block of rock in the Tptpll unit will be exposed by excavating an L-shaped alcove off the left rib of the ECRB Cross Drift. The rock will be heated by 5-meter long rod heaters placed in parallel holes in a horizontal plane. With the progress of heating, the moisture in the rock surrounding the heaters should be driven off, and a roughly cylindrical volume of dry rock should develop and grow around each heater. The water from the dried rock should be driven by the heat in all directions and should condense as the vapor reaches the cooler regions away from the heaters. The condensed liquid should drain down by gravity via the fractures and other openings in the rock.

Collection holes, which are parallel and perpendicular to the heaters, will be located below the heater plane. These holes are strategically placed immediately below the anticipated boiling zone around the inner heaters, and are designed to intercept any liquid water that may travel to them. Samples of any water collected in these holes may be analyzed in the laboratory.

Tiltmeters capable of recording rock movement of extremely small magnitude will be installed in drillholes. The tiltmeter measurements will enable the displacement field caused by the thermal expansion of the heated block to be delineated. This information and the measured temperature field can be used to quantify the coefficient of thermal expansion of the rock mass.

Probes to monitor microseismic or acoustic emissions may be installed in several holes. The probes may be installed prior to alcove excavation so that microseismic activities caused by the excavation process may be recorded.

It is planned the heating in the CDTT will be maintained for 9 to 12 months. Toward the end of the heating period, after approximately seven-and-a-half months of heating, water will be released in measured quantities in the injection hole. Water will be released at intervals of 7 to 10 days and its movement through the various sectors of rock heated to different temperatures will be tracked. (YMP 2001)

6.15 INFILTRATION/PERCOLATION MONITORING BOREHOLES

Infiltration/percolation monitoring involves the drilling of short (nominally less than 30 m long) boreholes vertically downward (typically within 10 degrees of vertical) from the ESF invert. The objectives of these tests are to monitor the infiltration/percolation of liquids below the ESF and are implemented in FWP-ESF-96-004 (YMP 2000c). As indicated in Mitchell (1997e), the proposed tests are conducted at three locations along the TS Main Drift. The infiltration/percolation monitoring boreholes in the TS Main Drift are single downward boreholes at each location. A process similar to that used for placement of convergence pins holes is used to penetrate the inverts at the proposed locations. A drill rig is used to extend the borehole to the desired depth. Testing locations are selected due to their higher than average water exposure during ESF construction and to limit their impacts to ongoing construction activities (i.e., so as to not interfere with the Heated Drift testing activities).

Per Mitchell (2000a), two vertical downward boreholes in Alcoves #3 and #4 will be used for additional infiltration/percolation monitoring. Instrumentation consisting of heat dissipation probes and tensiometers will be installed in the boreholes. The instrumentation will be confined in the boreholes with a mixture of Overton type sand and Bentonite clay plugs, encased in a PVC pipe. No additional water is planned to be added to these boreholes.

Three ECRB Starter Tunnel infiltration/percolation monitoring boreholes vary slightly from those in the TS Main Drift. These boreholes are located at the end of the ECRB Starter Tunnel just ahead of the launch point of the ECRB TBM. These holes are angled underneath the TBM excavation path, and are instrumented more heavily than the TS Main Drift boreholes. They monitor liquid infiltration/percolation immediately below the TBM operation area. Additional, near-vertical boreholes similar to those in the TS Main Drift drilled in the ECRB Cross Drift, before crossing the TS Main Drift.

6.16 GROUND SUPPORT IN THE VICINITY OF FAULT ZONES

Hollins (1997c) describes the extended excavation of the Southern Ghost Dance Fault Alcove (SGDFA, Alcove #7). Videos of borehole ESF-SAD-GTB#1 were used to explore ahead of the excavation in Alcove #7, and core samples from that borehole were also used to identify two strands (i.e., splays) of the Ghost Dance Fault (GDF) in the region of Alcove #7. The first strand encountered was the Western GDF strand at approximately Station 1+67 m from the centerline of the TS Main Drift. The second is the Eastern GDF strand at approximately Station 1+98 m from the centerline of the TS Main Drift. The TCO indicated that there was a need to conduct testing in the vicinity of these fault locations and that the use of dry-drilling and the prohibition of the use of Swellex rockbolts was desired.

6.17 TEMPORARY TESTING BULKHEADS

Temporary bulkheads are installed in support of various testing activities for selected underground locations. These bulkheads (not including the TTF Heat Drift bulkhead discussed above) are used to isolate a section of the ESF (primarily in alcoves) to conduct testing. Two bulkheads were also installed in the ECRB Cross Drift at approximated ECRB Stations 17+63 and 25+03 to isolate a large section of the drift for an approximate 1-year duration. Additionally, a refuge station may be constructed at ECRB Station 17+59 (Schulenburg 2000). A third bulkhead was installed beyond the second bulkhead (i.e., beyond Station 25+03) to better isolate the test area (Peters 2000). The installation of the bulkheads (similar to the niche study bulkheads discussed above) is coordinated with the TCO and appropriate PIs. Erection of a bulkhead typically involves installation of a steel set to which the bulkhead is attached. The steel set is typically sealed to the excavated rock surface using a wire mesh and shotcrete combination. Sodium silicate may also be used to improve the sealing around the bulkheads. The goal is to achieve a near airtight seal at the point of bulkhead installation. The bulkheads are provided with penetrations for access doors and cableways as required. These bulkheads are considered temporary and will be removed before Repository operation. (CRWMS M&O 1997g; Peters 2000)

6.18 ALCOVE #2 EXHIBIT AREA

Alcove #2, also known as the Bow Ridge Fault Alcove, is located on the right rib of the TS North Ramp at approximately Station 2+00 m. The alcove was constructed to conduct hydrologic testing within the nearby Bow Ridge Fault (which is located at approximately Station 2+20 m of the ESF North Ramp). Instrumentation packages are currently installed in nominally horizontal boreholes that emanate from the left rib of the alcove (at about five and eight meters from the end of the alcove). Instrument readouts are obtained periodically.

As described in Ricketts (1997) and YMP (1997e), Alcove #2 was converted for use as an exhibit area. An elevated, steel walkway was erected along the right rib of the North Ramp to allow visitor access. The walkway extends from the approximate location of the North Portal (or Alcove #1 area) to the entrance of Alcove #2. A similar, second elevated walkway (of approximately 30 m in length) may also be erected along the TS North Ramp from Alcove #2 to the location of the fault. This walkway would allow visitors the opportunity to observe the Bow Ridge Fault. These walkways may be freestanding (i.e., not connected to the existing steel sets) or may attach to the steel sets using clamps or bolts through existing bolt holes. No new holes are to be drilled in the steel sets, and no welding on the steel sets will be performed. The walkways are considered temporary and are erected such that they are removable.

Handrails were also erected inside Alcove #2 to define the visitor area and to prevent visitor access to the testing borehole collars and associated instrumentation. A full or partial concrete slab floor was also installed. Improved lighting (i.e., approximately 36 lighting fixtures and emergency lighting fixtures) and ground support were added, as well as a podium and a sound system. Ventilation enhancements (i.e., a new fan [with silencer] and additional ductwork) was installed. The electrical system was expanded as necessary to support these additional electrical loads. Various exhibits and hands-on demonstrations were placed in the exhibit area. Access for visitors is restricted to periodic guided tours only. (Ricketts 1997; YMP 1997e)

6.19 BUSTED BUTTE TESTING

The UZ Transport Test at Busted Butte is located to the south-southeast of the TS Loop (approximately 3.3 miles from the South Portal) and is outside the CCAB. Although, not a part of the TS Loop, the proposed testing is a subsurface testing activity and is controlled by FWP-

ESF-97-002 (YMP 1999e). These construction and testing activities provide access to the CH geologic structure and are described in YMP (1999e). The Busted Butte Test includes a construction phase, three test phases, and a completion or decommissioning phase. The actual testing activities are subject to future budget and scientific constraints, such that all three phases of testing may not be performed.

The construction phase described in YMP (1999e) included road enhancements, highwall and pad construction, and excavation of an approximately 60-m-long drift. The excavation was accomplished by drill-and-blast. Additional excavation by mechanical means is also possible for mineback operations. The initial section of the drift is nominally 3 m in diameter with the final approximately 25 m (i.e., the drill bay or test room section) being nominally 5 to 7 m in diameter. An additional drill bay was excavated off the right rib near the middle of the test room section to provide access to a second face of the test block(s). The drift originates in the lower vitrophyre and was excavated to penetrate the entire layer of the CH formation. The minimum ground cover above the test block is approximately 15 to 20 m.

YMP (1999e) describes three distinct and separate testing phases. In the first phase, a series of approximately eight nominally two-meter-deep boreholes are dry-cored along the left rib of the drift. These boreholes are used to: (1) collect core samples for analysis, (2) install moisture monitoring equipment, and (3) carry out initial tracer tests. This initial phase was planned for approximately five to six months with overcoring of the two-meter-deep boreholes at the end of testing to provide preliminary transport data. In cases where some or all of the sorptive tracers migrated imperceptibly from the injection source, the overcoring allows the determination of the detailed spatial distribution of the tracers via laboratory analysis. Microspheres were used in the boreholes to determine the movements of colloids associated with a liquid front into partially saturated tuffs.

The first phase of testing includes limited mineback operations and overcoring. Mineback operations involve spading off in 30 to 50 cm intervals. The mineback volume will be approximately four meters wide by four meters high by two to three meters deep. A steel-reinforced shotcrete pillar will be used on either side of the test area for support. There are about four overcores planned. (YMP 1999e)

The first phase of testing includes monitoring of the humidity, barometric pressure, and temperature of the air in the main drift began as soon as possible after excavation and will be continued throughout the course of operations. These data, together with instrumentation in boreholes, are used to assess whether perturbations from the main drift are negligible over the testing time frame. In addition, at least one approximately one meter cube of CH rock was removed for off-site testing. Concurrent geologic, hydrologic, and geochemical laboratory tests were conducted to complete scoping calculations for the second test phase. (YMP 1999e)

YMP (1999e) describes the second phase of the testing as including the dry-coring of about 28 boreholes approximately 10 m deep to allow for injection and monitoring of tracers in a test block. These holes consisted of 10 injection holes, 12 collection holes, and ERT holes. Collection boreholes were distributed so as to intercept potential tracer pathways as determined from the first phase data collected and modeling performed. These boreholes were configured to activate the largest possible volume of the second phase test block and accommodate the transport scaling test. Among other methods, video, neutron, and air permeability logging were performed pretest. ERT, neutron logging, and penetrating radar methods are used to assess the tracer front progression at selected time intervals. Microspheres are being used in the tracer solutions to simulate the movements of colloids associated with the liquid front into partially saturated tuffs. Chemicals (analogues of radionuclides) are being injected and collected to determine unsaturated hydrologic properties of the tuffs at the Busted Butte test facility. The advance of the tracer plume is also monitored within the test block using the geophysics methods described above, as well as neutron logging and collection pad analyses. Concurrent geologic, hydrologic, and geochemical laboratory tests are conducted throughout the second phase so as to complete scoping calculations for third test phase. This approach is intended to allow time for the new data to be processed such that it can be used in the process models that support License Application and Total-System Performance Assessment (TSPA) activities. The first two phases of testing characterize unsaturated tracer testing zones.

At the completion of the injection portion of the second phase, a partial mine-back operation may be performed to get a detailed picture of the three-dimensional tracer distribution within the test block. This would allow validation of the various geophysical methods used to evaluate the tracer movement during the test. The faces of the mine-back would be surveyed, photographed using normal and black light sources, mapped, and sampled to provide the tracer distribution throughout the block. A mine stability evaluation and design would be conducted prior to the mine-back to ensure a safe operation. Necessary ground support would be added prior to (if necessary) and during this excavation operation based on safe mining procedures and the ground support evaluation and design (YMP 1999e). CRWMS M&O (2000d) provides additional details on the mineback of this second phase of testing at Busted Butte.

The final phase of the testing, if implemented, includes air injection (i.e., pneumatic) testing is performed initially to identify potential "fast pathways" within the second test block before initiating saturated-tracer tests. The purpose of these tests is to characterize the rock in the vicinity of the second test block and to determine the variability of flow rates that might be encountered in the tuff units, under partially saturated conditions. Approximately 28 boreholes approximately 10 m deep would be dry-cored in a fashion similar to the second phase of testing described above. Single hole tests provide a measure of the permeability variation along the boreholes and crosshole packer tests measure the air flow through the rock mass and identify any possible pneumatic "fast pathway" between the boreholes. Following this pneumatic characterization of the test block, locally saturated transport tests are conducted in the boreholes using a different set of tracers from those used in the unsaturated tests and, thus, differentiate the tests. Microspheres may be used in the boreholes to simulate colloid movement in CH. Extensive continuous and/or pulse injections of conservative and nonconservative liquid tracer mixtures are used. The saturated tests involve faster water fluxes and, therefore, affect a larger area than the unsaturated transport tests. This testing phase concludes with overcoring and/or a partial mineback of the second test block. Concurrent geologic, hydrologic, and geochemical laboratory tests are conducted throughout this phase, and the results are integrated with the previous testing phases. (YMP 1999e)

The completion or decommissioning phase described in YMP (1999e) includes test close-out, demobilization, and reclamation activities. The tracers and other TFMs proposed for use in the Busted Butte UZ Transport Test are included in Attachment II. These include the additional TFMs requested in Brake (1998b).

6.20 TFM USE

TFM usage has been discussed in the text of Sections 6.1 through 6.19, as appropriate. For TFMs that were not specifically/individually discussed in Sections 6.1 through 6.19, CRWMS M&O (1999a) has previously evaluated an extensive list of TFMs that are approved for use in the Subsurface ESF. Attachment II contains a comprehensive list of TFMs (i.e., a list of TFMs that have been either previously evaluated by CRWMS M&O (1999a, 2000a), or specifically evaluated by subsequent sections of this DIE), which are approved for use in subsurface testing-related activities evaluated herein. However, the Attachment II TFMs are approved for use in these testing activities, provided their use and quantities are consistent with the restrictions established in Section 13.3 and Attachment II of this DIE.

Per Assumption 4.4, the use of TFMs is controlled by the requirements of the TFM procedure (AP-2.17Q). The use of any TFM within the Subsurface ESF that is not listed in Attachment II requires an evaluation per AP-2.17Q, before its use. However, only those TFMs that are permanently committed within the Subsurface ESF are required to be reported per the requirements of AP-2.17Q.

7. EVALUATED CONDITIONS

The following potential events and activities were considered for evaluation: earthquakes, rockfall, use of and inadvertent spills of oil and other fluids, fires, explosions, ground water inflow, and use of water and compressed air. These events and activities are used to evaluate the temporary items discussed above (Section 6) using the criteria in NLP-2-0.

Fires and explosions are evaluated with regard to potential impacts. Disruption of items as a result of earthquakes, fire, and explosions are not specifically evaluated in this DIE; however, deterministic failure of systems and components is used to assess the potential impacts on site characterization activities and waste isolation.

Given the DIE Requirements discussed below for spill protection/containment and clean-up of released fluids, the quantities of committed fluids (other than water) retained at the site from any credible equipment or vehicle accident or failure are expected to have negligible impacts on waste isolation and site characterization testing. In addition, the reporting of any committed fluids resulting from a spill, with subsequent evaluations of potential impacts to site characterization and waste isolation capabilities from those fluids, enables identification of any additional controls which may be appropriate to minimize potential impacts from accidental losses of such fluids. CRWMS M&O (1999a) includes an evaluation of the larger quantities of fluids (other than water) used by underground equipment.