U.S. DEPARTMENT OF ENERGY
OFFICE OF CIVILIAN RADIOACTIVE WASTE MANAGEMENT

NUCLEAR WASTE TECHNICAL REVIEW BOARD HYDROLOGY AND GEOCHEMISTRY PANEL MEETING

SUBJECT: SITE-CHARACTERIZATION APPROACH AND TIES TO PERFORMANCE ASSESSMENT (PA)

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PRESENTER'S TITLE AND ORGANIZATION: HYDROLOGIST
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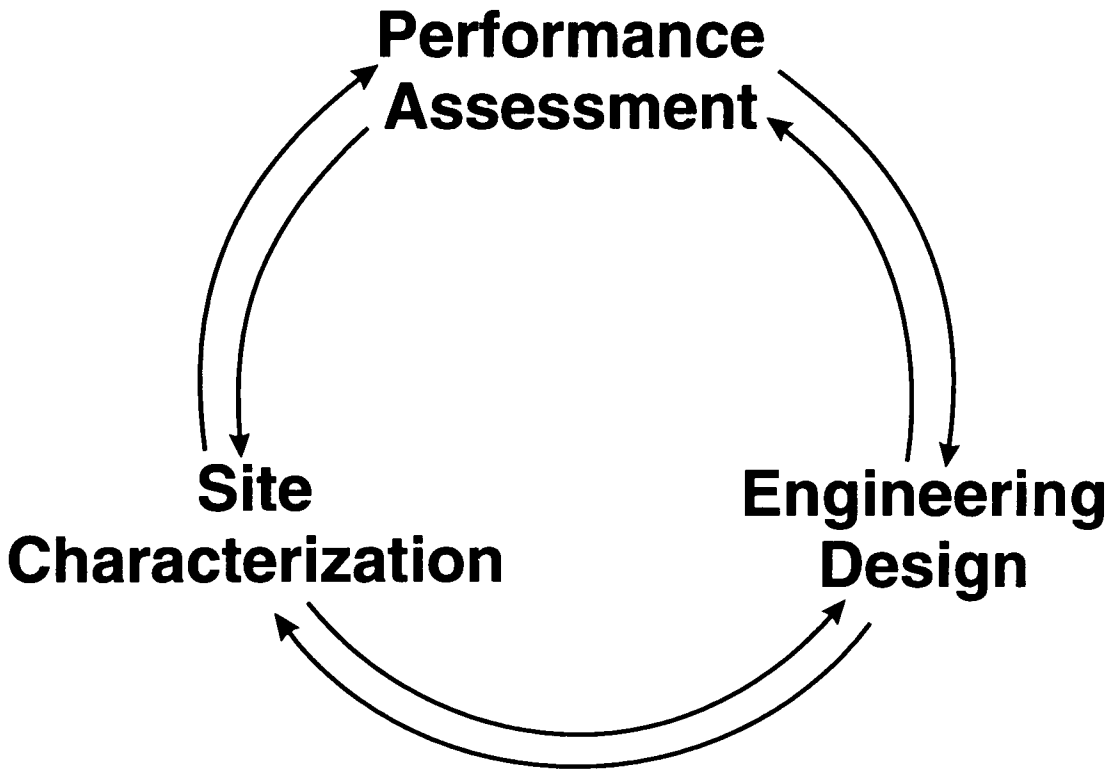
LAS VEGAS, NEVADA

Performance Assessment Paradox

- Site characterization collects data that performance assessment can't use
- Performance assessment needs data that site characterization can't measure

-- Piet Zuidema
U.S. DOE/NAGRA Site Characterization/
Performance Assessment Workshop,
Albuquerque, NM, May 18-20, 1994

PA, Site, and Design Triad

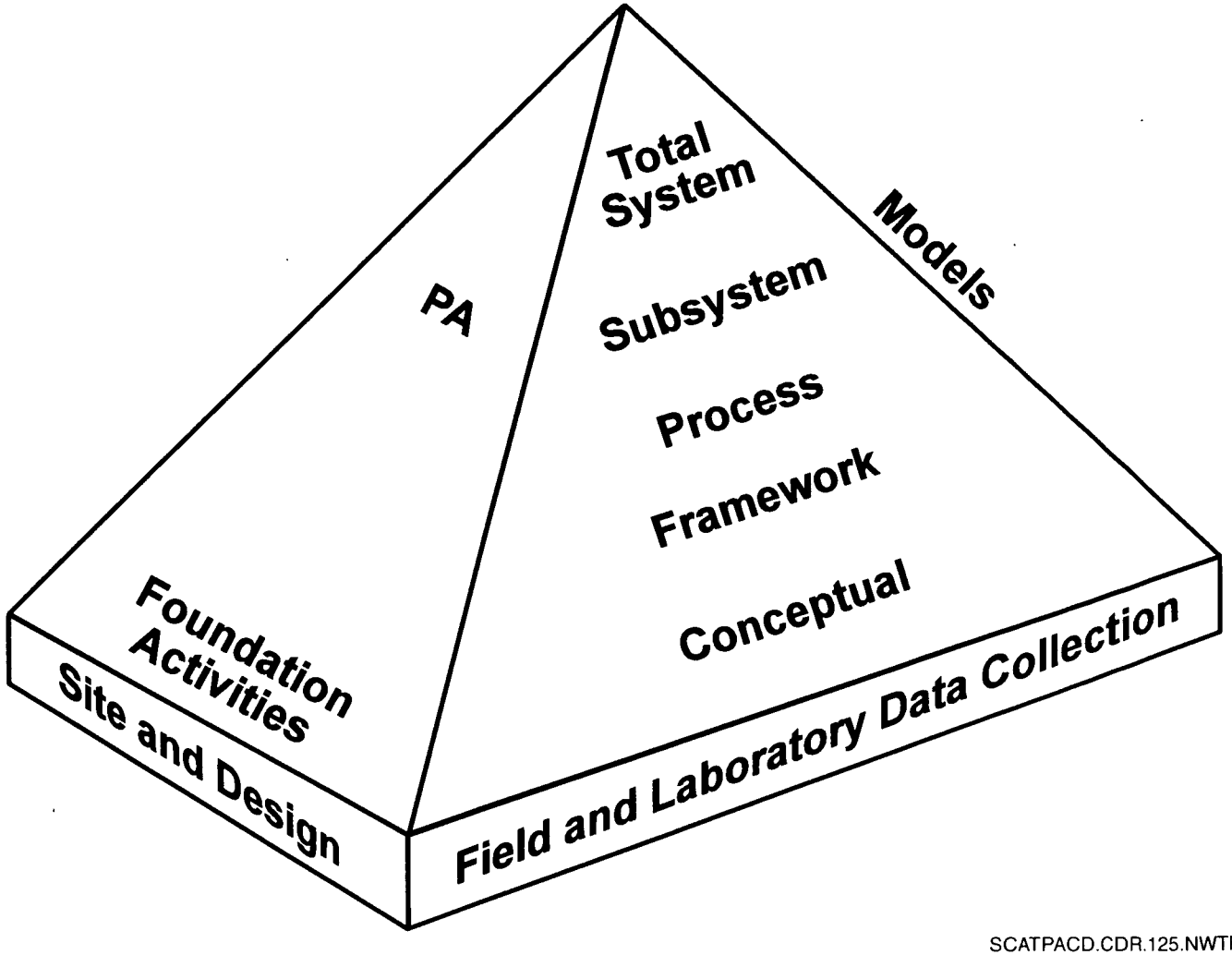


Foundation Activities

Foundation Activities

- **Site characterization**
  - Properties of the natural barrier system
- **Engineering design**
  - Properties of the engineered barrier system and its components

A Pyramid of Models



A Plexus of Models - 1

Conceptual Model	**Hypotheses concerning the state of a system and the processes controlling system state and evolution**
Framework Model	**A representation of system structure and geometry**

A Plexus of Models - 2

Process Model	**Generally, a mathematically based representation of the processes controlling the state of a system or subsystem**
Subsystem Model	**Generally, a quantitative representation of the response of a system or subsystem to one or more controlling processes**

A Plexus of Models - 3

Total-System Performance-Assessment Model

A quantitative representation of a system that is adequate to evaluate the capability of the system to satisfy specified performance objectives

Information Needs from TSPA-93

- Determination of dominant ground-water flow mechanisms in the unsaturated zone, i.e., porous-medium flow vs. flow in preferential pathways
- Rock-mass bulk permeability and CO_2 adsorption characteristics to evaluate gaseous ^{14}C transport
- Spatial and temporal distribution of ground-water flux at the proposed repository horizon
- Horizontal and vertical dispersive properties for ground-water flow and transport in the saturated zone
- Scaling of measured data for input to computational models

Information Needs from TSPA-93

(Continued)

Planned testing in the ESF

ALCOVE LOCATIONS IN THE ESF

The following illustrations show the probable locations of alcoves to be located in the ESF. The legends show the alcoves that are to be deferred and those that are to be built during Tunnel Boring Machine operations. The table below outlines which alcoves are to be built during TBM excavation.

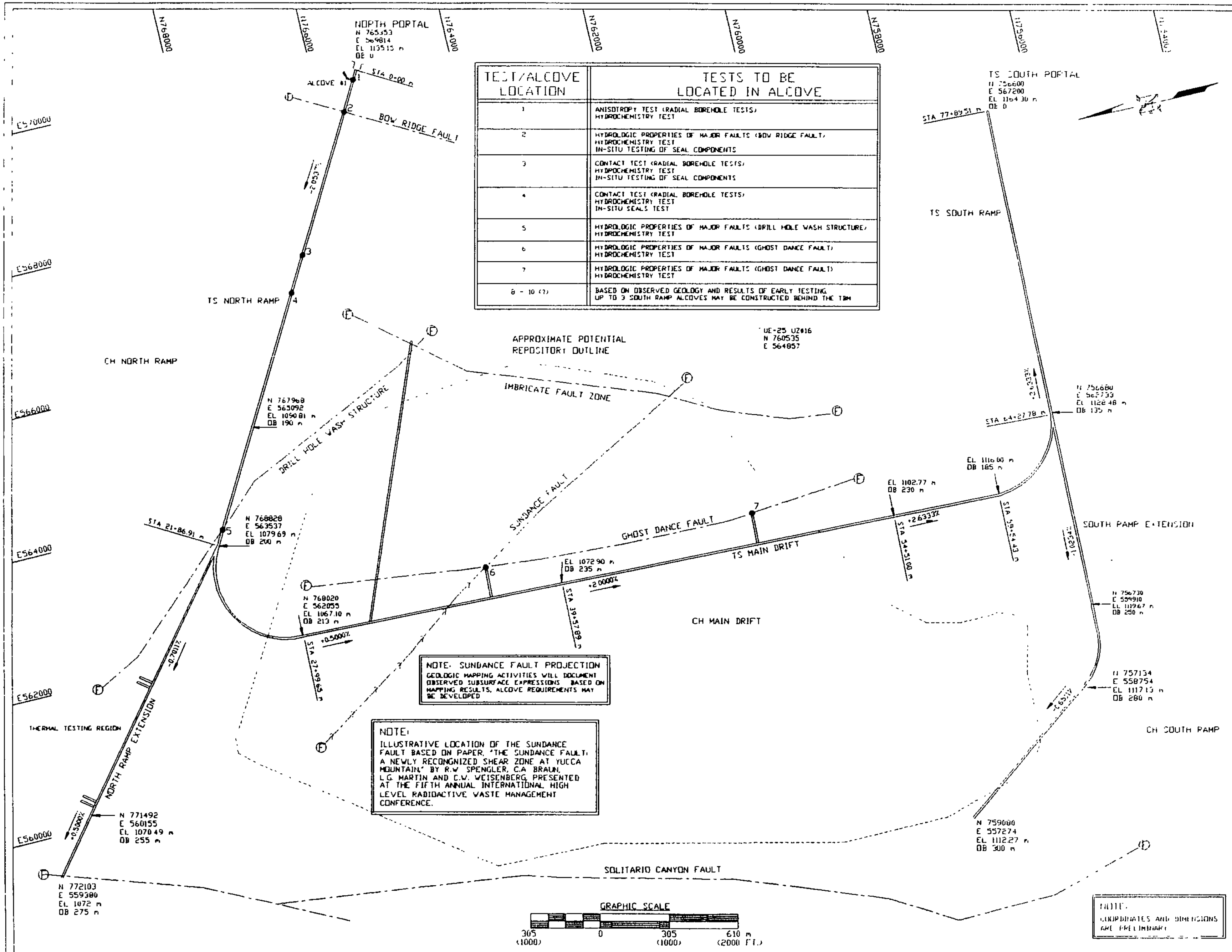
TEST/ALCOVE LOCATION	TESTS TO BE LOCATED IN ALCOVE
1	ANISOTROPY TEST (RADIAL BOREHOLE TESTS) HYDROCHEMISTRY TEST
2	HYDROLOGIC PROPERTIES OF MAJOR FAULTS (BOW RIDGE FAULT) HYDROCHEMISTRY TEST IN-SITU TESTING OF SEAL COMPONENTS
3	CONTACT TEST (RADIAL BOREHOLE TESTS) HYDROCHEMISTRY TEST IN-SITU SEALS TEST
4	CONTACT TEST (RADIAL BOREHOLE TESTS) HYDROCHEMISTRY TEST IN-SITU SEALS TEST
5	HYDROLOGIC PROPERTIES OF MAJOR FAULTS (DRILL HOLE WASH) HYDROCHEMISTRY TEST
6	HYDROLOGIC PROPERTIES OF MAJOR FAULTS (GHOST DANCE FAULT) HYDROCHEMISTRY TEST
7	HYDROLOGIC PROPERTIES OF MAJOR FAULTS (GHOST DANCE FAULT) HYDROCHEMISTRY TEST
8 - 10?	BASED ON OBSERVED GEOLOGY AND RESULTS OF EARLY TESTING, UP TO 3 SOUTH RAMP ALCOVES MAY BE CONSTRUCTED BEHIND THE TBM.

LEGEND

FAULT ZONE
RAMP CONFIGURATION
REFERENCE GRID
BOREHOLE LOCATION

REQUIRED (CONSTRUCTION '94 - '96) ALCOVE LOCATIONS

OB = APPROXIMATION OF OVERBURDEN (SURFACE ELEVATION EXTRAPOLATED FROM BOREHOLE ELEVATIONS)



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5	HYDROLOGIC PROPERTIES OF MAJOR FAULTS (DRILL HOLE WASH STRUCTURE) HYDROCHEMISTRY TEST
6	HYDROLOGIC PROPERTIES OF MAJOR FAULTS (GHOST DANCE FAULT) HYDROCHEMISTRY TEST
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8 - 10 (?)	BASED ON OBSERVED GEOLOGY AND RESULTS OF EARLY TESTING UP TO 3 SOUTH RAMP ALCOVES MAY BE CONSTRUCTED BEHIND THE TBM

NOTE: SUNDANCE FAULT PROJECTION
GEOLOGIC MAPPING ACTIVITIES WILL DOCUMENT OBSERVED SUBSURFACE EXPRESSIONS. BASED ON MAPPING RESULTS, ALCOVE REQUIREMENTS MAY BE DEVELOPED.

NOTE:
ILLUSTRATIVE LOCATION OF THE SUNDANCE FAULT BASED ON PAPER, "THE SUNDANCE FAULT: A NEWLY RECOGNIZED SHEAR ZONE AT YUCCA MOUNTAIN" BY R.W. SPENGLER, C.A. BRAUN, L.G. MARTIN AND C.W. WEISENBERG, PRESENTED AT THE FIFTH ANNUAL INTERNATIONAL HIGH LEVEL RADIOACTIVE WASTE MANAGEMENT CONFERENCE.

NOTE:
COORDINATES AND DIMENSIONS ARE PRELIMINARY

LOS ALAMOS NATIONAL LABORATORY
TEST COORDINATION OFFICE - YUCCA MOUNTAIN PROJECT
PROJECT: LITHOLOGIC CONTACT AND FAULT LOCATION ILLUSTRATION

CAD FILE:	AUTOCAD R12	SIZE: A	SCALE: NOTED	REVISION: A1
DRN BY: D.J. WEAVER	APPROVED BY: ON FILE - NZ ELKINS/PD OLIVER	DATE DRN: 6/1/94	PLOT DATE: 1/7/94

NOTES:
-ADMINISTRATIVE/ILLUSTRATIVE USE ONLY

ILLUSTRATION BASED ON M&O DRAWING #BAB000000-01717-2100-40001-0B "EXPLORATORY STUDIES FACILITY PACKAGE 2A OVERALL SUBSURFACE GENERAL ARRANGEMENT PLAN"

TWO THOUSAND FEET GRID. ENGLISH COORDINATES ARE BASED ON THE NEVADA STATE COORDINATE SYSTEM, CENTRAL ZONE

DIMENSIONS AND ELEVATIONS ARE SHOWN IN METERS. METERS ARE ROUNDED TO TWO DECIMAL PLACES. WHERE DISCREPANCIES BETWEEN ELEVATIONS AND GRADIENTS OCCUR DUE TO ROUNDING ELEVATIONS WILL GOVERN.

STARTER TUNNEL CONFIGURATION AND AZIMUTH FOR THE FIRST 60.960 m (200 FT) IS BASED ON TITLE II PACKAGE 1A DESIGN DRAWINGS

EXISTING DRILLHOLE LOCATIONS ARE BASED ON FIELD SURVEYS. PROPOSED DRILLHOLE LOCATIONS ARE BASED ON INFORMATION CONTAINED IN THE WORK PROGRAMS AND FROM GENESIS, "BOREHOLE LOCATIONS FOR YUCCA MOUNTAIN PROJECT," NP94012703

EXISTING DRILLHOLE LOCATIONS ARE BASED ON FIELD SURVEYS. PROPOSED DRILLHOLE LOCATIONS ARE BASED ON INFORMATION CONTAINED IN THE WORK PROGRAMS

LITHOLOGY BASED ON THE FOLLOWING REFERENCES: "ONE USGS BASE DRAWING (11-8-93) BY USGS, MODIFIED BY C. BRECHTEL (1-13-94) ... FROM USGS OPEN FILE REPORT 94-494, PRELIMINARY GEOLOGIC MAP ... NO 98-60-09 "DESIGN PACKAGE 2A MINING CALCULATIONS ... NORTH RAMP COORDINATE GEOMETRY CALCULATIONS" AND ... ENHANCEMENTS TO THE CURRENT ESF CONFIGURATION AND ... 1993 GEOLOGIC CROSS SECTIONS OF PROPOSED UNDERGROUND EXCAVATIONS, EXPLORATORY STUDIES FACILITY, FEBRUARY 1993"

FAULT TRACE LOCATIONS, EXCEPT FOR THE BOW RIDGE FAULT, ARE APPROXIMATIONS BASED ON AT-DEPTH PROJECTIONS OF INFORMATION FROM USGS OPEN FILE REPORT 84-494, PRELIMINARY GEOLOGIC MAP AND SECTIONS, BY SCOTT AND BONK. THE BOW RIDGE FAULT TRACE IS AN AT-DEPTH PROJECTION BASED ON PRELIMINARY FIELD WORK FROM ON-GOING ROCK AND SOIL INVESTIGATIONS.

Additional material provided by the ESF Test Coordination Office Los Alamos National Laboratory

THE EXPLORATORY STUDIES FACILITY

The Mission of the ESF

The Exploratory Studies Facility (ESF) is intended to provide underground access to the potential repository location (the Topopah Spring Welded Tuff formation) and a lower level, the Calico Hills formation. An "underground laboratory" will be developed in which a wide variety of tests will be performed. Of particular interest to Yucca Mountain scientists will be those rock properties that give an indication of the ability of the site to isolate high level radioactive waste over a 10,000 year performance period. The reaction of the rock to heating and cooling and the rate at which gasses and liquids can move through the rock mass will be studied in detail. Physical properties of the rock mass, particularly in and near faulted areas, will also be closely examined.

Facility Description

The facility will consist of two main access ramps from the surface ("North" and "South") to either end of a two mile long main tunnel running roughly North-South in the potential repository level, the Topopah Spring level. Two additional smaller diameter ramps will extend from the main ramps to either end of a second generally North-South tunnel in a lower level, the Calico Hills. Various side tunnels will be driven to provide access to fault zones and other potential areas of interest. 25,600 meters (84,000 feet) of tunnel will be excavated, resulting in approximately 1,910,000 tonnes (2,100,000 tons) of excavated rock.

Mechanical excavation methods will be used when possible. Conventional (drill & blast) excavation will be used only when necessary. In the upper level the rock is fairly hard; 155 megapascals (mPa) (22,500 pounds per square inch (psi) compressive strength (Note: Compare to normal concrete at about 28 mPa (4,000 psi))). A large diameter tunnel boring machine (TBM) will be employed to excavate this material in the main ramps and tunnels. Side tunnels on the upper level will be excavated by either the TBM, other similar mechanical means, or by drill and blast. In the lower level the rock is much softer, and can be mechanically excavated by several different types of machines.

Surface facilities will be built in three primary areas. The North portal area will consist of a 4.9 hectare (12 acre) pad with the primary office/warehouse complex, data acquisition system building, visitor center, portal control building, and substation. The South portal will have a 2 hectare (five acre) pad with the primary ventilation fan installation and several smaller structures. The Optional Shaft area, if constructed, will consist of a one hectare (two acre) pad, hoist and headframe, and minimal administrative/maintenance building.

The total construction time from the start of site preparation to the completion of all excavation is currently expected to be approximately seven years. This time span is based on currently anticipated funding levels and assumes that all currently planned basic and optional facilities are built.

Construction Sequence

Tunneling has begun at the North Portal and proceeds down the North Ramp to the Topopah Spring (TS) member, along the main TS drift, and up the South Ramp, breaking out on the surface at the South Portal. This first effort, called "The Loop":

- Covers a distance of approximately five miles
- Will provide a good first look at the TSL
- Will provide two separate paths of access to the underground facility.

Upon completion of the loop, excavation will begin on the Main Test Area (MTA) and the lateral tunneling on the TS. Under current plans, when all excavation is complete on the TS member, the South Ramp to the Calico Hills (CH) will be started. Similar to the TS loop, this excavation will proceed down the south ramp, along the CH Main Drift, and up the CH North Ramp, connecting into the TS North Ramp. Side tunneling in the CH member will be completed after the CH loop is done.

Scientific testing will be performed on a limited basis from the start of tunneling operations, and will expand after the completion of the initial loop and the MTA.

Current Status and Near Term Plans for the ESF

Preliminary design of the ESF was completed in September, 1991. Final design began, in a phased manner, in October, 1991. The first portion, or "Design Package", was completed in October, 1992. Construction of the North Portal surface area began on November 30, 1992. Currently, a 60 meter (200 feet) "starter tunnel" is accepting the TBM which is being assembled in preparation for the start of tunneling operations in September, 1994.

The final design of the next two design packages is underway. These packages include the surface buildings to be located at the North Portal, and the north ramp from the surface to the TSL.

ESF construction plans for FY 94 include erection of the TBM and limited construction of surface utilities and buildings at the North Portal.

Exploratory Studies Facility (ESF) North Ramp Alcove #I

General Description:

Located at station CS 0+43.3 (1+40 feet) in the ESF north ramp starter tunnel with an alcove size of approximately 4.6 x 4.6 m (15 x 15 ft) in cross section by 29.3 m (96 ft) in length. Final depth was determined in the field based on geologic and test considerations.

Primary Tests:

1. Anisotropic Radial Borehole Test:

Anisotropy testing consists of three-corehole sites (which replace the earlier long radial borehole testing) with planned single- and cross-hole air injection tests designed to measure the 3-dimensional air permeability of the Upper Tiva Canyon hydrogeologic unit. Testing consists of three 30-meter (100 ft), HQ-3 coreholes drilled in a triangular pattern, diverging with depth. Coreholes will be instrumented with pneumatic packers and sensors and cross-hole air injection tests will be conducted.

2. Hydrochemistry Tests:

These tests will 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 coreholes. The ESF will provide access for the collection of gas, rock, and fracture-water samples. A series of short borehole gas sampling stations, and long-term monitoring of the long radial borehole test coreholes are provided in the alcove.

Supporting Tests:

1. Underground Geologic Mapping:

Geologic mapping and photogrammetry is used to document lithologic and fracture variability throughout the vertical and horizontal extent of the alcove, to investigate structural features, and to provide siting data to confirm (or modify) planned test locations.

2. Construction and Rock Mass Monitoring:

This test in alcove #I consists of three activities, evaluation of mining methods (to monitor and evaluate excavation methods and rock responses), monitoring of ground support systems (to develop recommendations for ground support systems in drifts), and monitoring drift stability (to monitor drift convergence using multi-point borehole extensometers and borehole pressure cells).

3. Consolidated Sampling

Rock samples for mineralogy/petrology and the geohydrology analyses have been collected in alcove #I by USGS/USBR Geologic mappers under their consolidated sampling role for three study plans: 8.3.1.3.2.2 (History of Mineralogic and Geochemical Alteration of Yucca Mountain); 8.3.1.2.2.2 (Water Movement Test); and 8.3.I.3.2.1 (activities: Mineral Distributions Between the Host Rock and Accessible Environment and Fracture Mineralogy).

4. Perched-Water Tests:

The purpose of the perched-water test is to detect the occurrence, and delineate the lateral and vertical extent, of perched-water zones (if encountered) during excavation of the ESF, to identify perching mechanism(s), and to sample perched-water for chemical analyses. Because there is significant uncertainty regarding the likelihood of encountering perched-water, this test is categorized as a "contingency test." Preparation to field tests for characterization of any saturation zones encountered in alcove #I has been maintained.

EXPLORATORY STUDIES FACILITY
UNDERGROUND TESTING DURING CONSTRUCTION

TEST EVENT NAME	TEST NAME (SCP ACTIVITY)	STUDY PLAN NAME	TEST LOCATION
Geologic Mapping ESF	Underground Geologic Mapping (8.3.1.4.2.2.4)	Characterization of Structural Features in the Site Area	Throughout ESF
Perched Water (Contingency)	Perched Water Testing in the ESF (8.3.1.2.2.4.7)	Characterization of the Yucca Mountain Unsaturated-Zone in the ESF	As Encountered
Consolidated Sampling ESF	Matrix Hydrologic Properties Testing (8.3.1.2.2.3.1)	Characterization of the Yucca Mountain Unsaturated-Zone Percolation	Sampling Throughout ESF
	History of Mineralogic and Geochemical Alteration of YM (8.3.1.3.2.2.1)	Study Plan for History of Mineralogic Alteration of Yucca Mountain	Sampling Throughout ESF
	Petrologic Stratigraphy of the Topopah Spring Member (8.3.1.3.2.1.1)	Study Plan for Mineralogy, Petrology, and Chemistry of Transport Pathways	Sampling Throughout Topapah Spring Member
	Mineral Distributions Between Host Rock and Accessible Environment (8.3.1.3.2.1.2)	Study Plan for Mineralogy, Petrology, and Chemistry of Transport Pathways	Sampling Throughout ESF
	Fracture Mineralogy (8.3.1.3.2.1.3)	Study Plan for Mineralogy, Petrology, and Chemistry of Transport Pathways	Sampling Throughout ESF
	Chloride and Chlorine-36 Measurements of Percolation at Yucca Mountain (8.3.1.2.2.2.1)	Water Movement Test	Sampling Throughout ESF
	Biological Sorption and Transport (8.3.1.3.4.2)	Biological Sorption and Transport	Sampling Throughout ESF
	Density & Porosity Characterization (8.3.1.15.1.1)	Laboratory Thermal Properties	Sampling Throughout ESF
	Volumetric Heat Capacity Characterization (8.1.3.15.1.2)	Laboratory Thermal Properties	Sampling Throughout ESF
	Thermal Conductivity Characterization (8.3.1.15.1.1.3)	Laboratory Thermal Properties	Sampling Throughout ESF
	Thermal Expansion Characterization (8.3.1.15.1.2.1)	Laboratory Thermal Properties	Sampling Throughout ESF
	Compressive Mechanical Properties of Intact Rock at Baseline Experiment Conditions (8.3.1.15.1.3.1)	Laboratory Determination of the Mechanical Properties of Intact Rock	Sampling Throughout ESF

EXPLORATORY STUDIES FACILITY
UNDERGROUND TESTING DURING CONSTRUCTION (Continued)

	Effects of Variable Environmental Conditions on Mechanical Properties (8.3.1.15.1.3.2)	Laboratory Determination of the Mechanical Properties of Intact Rock	Sampling Throughout ESF
	Mechanical Properties of Fractures at Baseline Conditions (8.3.1.15.1.4.1)	Laboratory Determination of the Mechanical Properties of Fractures	Sampling Throughout ESF
	Effects of Variable Environmental Conditions of Mechanical Properties of Fractures (8.3.1.15.1.4.2)	Laboratory Determination of the Mechanical Properties of Fractures	Sampling Throughout ESF
	Repository Horizon Rock-Water Interaction (8.3.4.2.4.4.2)	Engineered Barrier System Field Tests	Sampling Throughout Topopah Spring Member
	Geochemical Assessment of Yucca Mountain in Relation to the Potential for Mineralization (8.3.1.9.2.1.1)	Natural Resource Assessments of Yucca Mountain, Nye County, Nevada	Sampling Throughout ESF
	Studies of Calcite and Opaline Silica Vein Deposits (8.3.1.5.1.5)	Characterization of Yucca Mountain Quaternary Regional Hydrology	Sampling Throughout ESF
Radial Borehole Testing	Radial Borehole Tests in the ESF (8.3.1.2.2.4.4.)	Characterization of Yucca Mountain Unsaturated-Zone in the ESF	Throughout ESF
Hydrochemistry Testing	Hydrochemistry Tests in the ESF (8.3.1.2.2.4.8)	Characterization of Yucca Mountain Unsaturated-Zone in the ESF	Alcoves & Drifts Throughout ESF
Hydrologic Properties of Major Faults	Hydrologic Properties of Major Faults Encountered in the ESF (8.3.1.2.2.4.10)	Characterization of Yucca Mountain Unsaturated-Zone in the ESF	Alcoves at Identified Structures Throughout ESF
Construction Monitoring - ESF	Access Convergence Measurements (8.3.1.15.1.5.1)	Excavation Investigations	Throughout ESF
	Evaluation of Mining Methods (8.3.1.15.1.8.1)	In Situ Design Verification	Throughout ESF
	Monitoring of Ground Support Systems (8.3.1.15.1.8.2)	In Situ Design Verification	Throughout ESF
	Monitoring Drift Stability (8.3.1.15.1.8.3)	In Situ Design Verification	Throughout ESF
	Air Quality and Ventilation Experiment (8.3.1.15.1.8.4)	In Situ Design Verification	Throughout ESF