Rec 11/1/93
DCS

CENTER FOR NUCLEAR WASTE REGULATORY ANALYSES
Washington Office

MEETING/TRIP REPORT

November 5, 1993

SUBJECT: NRC Global Positioning System (GPS) activities in the Yucca Mountain region under direction of G. Birchard (NRC) and B. Wernicke (CalTech) - CNWRA participation in collection of data from sites at and near Yucca Mountain and along the Hunter Mountain and Northern Death Valley (right-lateral strike-slip) fault zones (20-5704-164)

DATE and PLACE: October 15-21, 1993 - Yucca Mountain and Region West of Yucca Mountain, Nevada/California

AUTHOR: G. Stirewalt

DISTRIBUTION:

<u>CNWRA</u>

W. Patrick
J. Latz
B. Sagar
Directors
Element Managers
C. Connor
B. Hill
S. Young

<u>SwRI</u>

S. Rowe (Contracts)

<u>NRC-HLW</u>

M. Knapp
S. Fortuna
B. Stiltenpole
B. Meehan
J. Linehan
R. Ballard
K. McConnell
D. Brooks

<u>NRC-RES</u>

B. Morris
F. Costanzi
M. Silberberg
J. Randall
B. Ott
G. Birchard

<u>NMSS Site Rep</u>

P. Justus

A26.1
NH15.1
WM-11

Delete all dist except CF
NRC PDR
NUDOCS Full Text
NUDOCS Abstract

170013

9402230316 931105
PDR WASTE
WM-11 PDR

CENTER FOR NUCLEAR WASTE REGULATORY ANALYSES
Washington Office

MEETING/TRIP REPORT

November 5, 1993

SUBJECT: NRC Global Positioning System (GPS) activities in the Yucca Mountain region under direction of G. Birchard (NRC) and B. Wernicke (CalTech) - CNWRA participation in collection of data from sites at and near Yucca Mountain and along the Hunter Mountain and Northern Death Valley (right-lateral strike-slip) fault zones

DATE and PLACE: October 15-21, 1993 - Yucca Mountain and Region West of Yucca Mountain, Nevada/California

AUTHOR: G. Stirewalt

PERSONS PRESENT:

NRC	Others
G. Birchard	California Institute of Technology (CalTech) - B. Wernicke, K. Snow & two graduate student assistants
	Smithsonian Institution Astrophysical Observatory, Cambridge, Massachusetts - J. Davis & two post-doctoral researchers
	University NAVSTAR Consortium (UNAVCO), Boulder, Colorado - B. Baker & one assistant

BACKGROUND AND PURPOSE:

As indicated by the favorable and potentially adverse conditions specified in 10 CFR Part 60 under 60.122(b)(1) and 60.122(c)(11) through (15), regulatory concerns exist about Quaternary deformation (faulting and seismotectonics) and igneous (tectonovolcanic) activity at the potential high-level radioactive waste site at Yucca Mountain. To analyze the contemporary strain history of the region around Yucca Mountain and understand its importance for control of faulting, seismotectonic, and tectonovolcanic activity, funding has been provided directly to B. Wernicke from NRC Research under a project managed by G. Birchard.

This project is organized to conduct GPS surveys in a tectonically active region of the Basin and Range which includes Yucca Mountain, the Northern Death Valley fault zone, and the Hunter Mountain fault zone. The northwest-southeast-trending Northern Death Valley fault zone lies northeast of Cottonwood Mountains in this tectonically complex region, and the subparallel Hunter Mountain fault zone bounds the Cottonwoods on the southwest (Snow and White, 1991). Both fault zones exhibit right-lateral strike-slip displacement and occur within the Death Valley region - an area considered to be the most strongly extended region in U.S. Cordillera characterized by right-lateral shearing with accompanying vertical-axis rotation of adjacent major blocks like the Black Mountains (Holm and Others, 1993) and possibly Bare Mountain (Snow and Wernicke, 1988; Holm and Others, 1993).

The purpose of the NRC-funded GPS effort is to acquire data across the Hunter Mountain and Northern Death Valley fault zones and in the vicinity of Yucca Mountain to ascertain the contemporary strain history (patterns and rates) of this region. The simplified sketch map of Figure 1 illustrates the position of the survey stations relative to these two fault zones and to the Bare Mountain fault. The GPS surveys are expected to provide reliable information on contemporary strain in this region in less than a decade, with detection limits for horizontal motion in the range of millimeters. The general procedure involves periodic measurement of the survey stations to determine their exact positions using satellite signals. Consequently, any contemporary tectonic movement can be detected and rates and patterns of the strain can be determined. This type of information will provide important input for alternative tectonic models of the Yucca Mountain region to be constructed by CNWRA and NRC staff members during prelicensing and license review for assessing information and models provided by DOE in relation to tectonic, seismic, and volcanic activity. Data acquired by continuation of this activity should prove important for evaluating potential hazards due to fault rupture, earthquakes, and igneous activity. Key technical uncertainties (KTUs) addressed by this effort are related to the following potentially adverse conditions specified in 10 CFR Part 60:

- 60.122(c)(11) - KTU is "development and use of conceptual tectonic models for structural deformation" - License Application Review Plan (LARP) Review Plan 3.2.1.5 (NRC, 1993).
- 60.122(c)(13) and (14) - KTU is "correlation of earthquakes with tectonic features" - LARP Review Plans 3.2.1.7 and 3.2.1.8 (NRC, 1993).
- 60.122(c)(15) - KTU is "development and use of conceptual models as related to igneous activity" - LARP Review Plan 3.2.1.9 (NRC, 1993).

CNWRA involvement in this on-going, NRC-funded GPS activity is part of the Task 4 FY94 field efforts outlined in the CNWRA Tectonics Research Project Plan (Young and Stirewalt, 1993). Based on consideration of the three KTUs related to tectonic features and models stated above, the CNWRA tectonics research project is organized to specifically support assessment and development of alternative regional tectonic models and structural models of faulting and associated deformation at Yucca Mountain. Participation by CNWRA staff in the GPS data collection effort provided direct knowledge of the method, immediate information on exact station locations, and a better understanding of the goals of the GPS activity - an effort at the forefront of contemporary strain analysis and essential for understanding how strain is partitioned in the region of study. Additional constraints for alternative tectonic models should be provided by the GPS effort, such that the specified KTUs can be better addressed.

Survey stations were first selected and data collection begun by B. Wernicke and his team in October 1991. No data were collected in 1992 for reasons that were not specified, although the current plan is to start annual collection of data beginning with the present 1993 survey campaign. Stations for the campaign utilized either previously-surveyed USGS benchmarks or newly-surveyed points

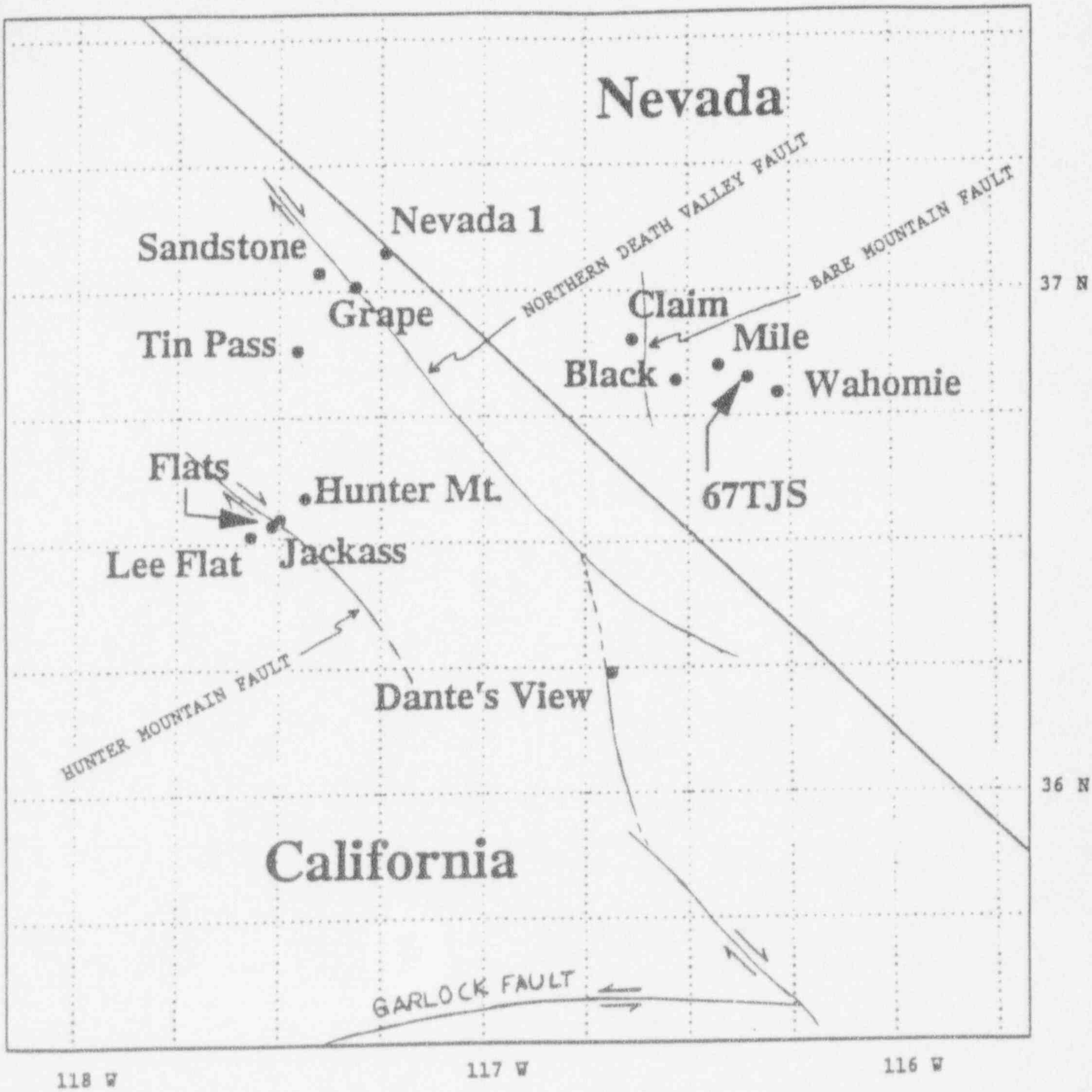


Figure 1. Sketch Map Showing Location of GPS Stations for October 15-19 Campaign Relative to Select Major Faults in the Yucca Mountain Region. Traces of Hunter Mountain and Northern Death Valley Fault Zones after Snow and White (1991).

placed by CalTech staff in 1991 under the direction and supervision of B. Wernicke. The stations occupied during this survey campaign, the same as those occupied in 1991, are listed below. Latitudes, longitudes, and particularly elevations are closely approximated values read from the receiver in the field. These values may be refined upon final processing of data by J. Davis at the Smithsonian Astrophysical Observatory. J. Davis and his staff are currently processing all survey data for the GPS project.

(1) Stations along the Hunter Mountain fault zone

"Lee Flats" - west side of fault
latitude 36° 29′ N, longitude 117° 37′ W, elevation 1700m.

"Flats" - west side of fault
latitude 36° 31′ N, longitude 117° 34′ W, elevation 1900m.

"Jackass" - east side of fault
latitude 36° 32′ N, longitude 117° 33′ W, elevation 1900m.

"Hunter" - east side of fault
latitude 36° 34′ N, longitude 117° 29′ W, elevation 2000m.

(2) Stations along the Northern Death Valley fault zone

"Tin Pass" - west side of fault
latitude 36° 52′ N, longitude 117° 30′ W, elevation 1500m.

"Sandstone" - west side of fault
latitude 37° 1′ N, longitude 117° 27′ W, elevation 700m.

"Grape" - near fault
latitude 37° 0′ N, longitude 117° 22′ W, elevation 700m.

"Nevada 1" - east side of fault
latitude 37° 4′ N, longitude 117° 17′ W, elevation 1200m.

"Dante" - east side of fault along the Black Mountains front
latitude 36° 14′ N, longitude 116° 44′ W, elevation 1664m.

(3) Stations in the Yucca Mountain vicinity

"Claim" - on Bare Mountain, west of Bare Mountain fault
latitude 36° 53′ N, longitude 116° 41′ W, elevation 1400m.

"Black" - near Black Cone, east of Bare Mountain fault
latitude 36° 49′ N, longitude 116° 34′ W, elevation 1000m.

"Mile" - crest of Yucca Mountain
latitude 36° 50′ N, longitude 116° 28′ W, elevation 1500m.

"67TJS" - near Fortymile Wash, east of Yucca Mountain
latitude 36° 49′ N, longitude 116° 24′ W, elevation 1000m.

"Wahomie" - east of Yucca Mountain
latitude 36° 47′ N, longitude 116° 22′ W, elevation 1100m.

Station "Nevada 1" was measured daily as the tie-in station for this survey campaign.

SUMMARY OF PERTINENT POINTS AND ACTIVITIES:

October 15 (Friday) - Training Day on Use of the GPS System in Beatty, Nevada

Survey teams were formed and thoroughly trained by B. Baker (UNAVCO) in use of the GPS system. Details of this training are too lengthy to be presented in this trip report. However, topics covered during the daylong training session included all aspects needed to set up equipment (receiver, tripod-mounted antenna, battery power supply), conduct the survey and assure data were being acquired, break down the equipment, charge the battery power supply (a necessary task each evening), and download the daily records from the receiver computer to floppy disc (also a necessary task each evening to assure that no data were lost).

We were instructed to apply an elevation mask of 15 degrees, so that no satellites below that "elevation" were used in this campaign. We were also informed that daily surveys were to be conducted at each station during an 8-hour period from 9:30am until 5:30pm to make optimal use of available satellites. The measurement interval was to be set for 30 seconds for all surveys. Attachment 1 presents a complete list of equipment required for setting up a station and collecting GPS data. It specifies names of manufacturers and model numbers for the equipment used during this survey campaign. Attachment 2 is a sample daily observation log which indicates information recorded during a survey. Attachment 3 is a sample form for description of the GPS stations.

October 16 (Saturday) - Deployment of Survey Teams to Stations along the Northern Death Valley Fault Zone

Teams were deployed to the following stations along the Northern Death Valley fault zone: Tin Pass, Sandstone, Grape, Nevada 1, and Dante. I worked at the Dante station with P. Elosegi, a post-doctoral researcher from Spain currently working with J. Davis at the Smithsonian Astrophysical Observatory.

We departed from Beatty at dawn in order to reach the Dante station in time to conduct a full 8-hour survey. However, due to driving time to the station from Beatty (about 1-1/4 hours) and time involved in moving equipment from the vehicle to the station across a rocky trail, we were set up and running about one hour late (i.e., 10:30am rather than 9:30am as we had hoped). The station was positioned atop volcanic rocks capping Dante's View. Data were successfully collected for a full 7 hours at this most spectacular location overlooking the deepest part of Death Valley - Badwater at an elevation of about 282 feet below sea level; roughly 6000 feet below the elevation of the station where we were located! (This setting certainly makes one believe in tectonism!) A total of 1005 records were obtained, using up to 8 satellites at a time (15 degree elevation screen and 30-second recording interval).

October 17 (Sunday) – Deployment of Survey Teams to Stations along the Hunter Mountain Fault Zone and to Station Nevada 1 for Tie-in

Teams were deployed to the following stations along the Hunter Mountain fault zone: Lee Flats, Flats, Jackass, and Hunter. P. Elosegi and I worked at the Jackass station.

All teams had a drive of about 2 hours from Beatty to reach the locations along the Hunter Mountain fault zone, so everyone departed before dawn. We were set up and running at this station by 9:24am and data were collected for an 8-hour period. The station was positioned on an exposure of the Hunter Mountain Pluton. The Saline Valley was visible to the north of the station and the Panamint Valley to the south. Immediately west of the station was the trace of the Hunter Mountain fault zone. A total of 1160 records were obtained, using up to 6 satellites at a time (15-degree elevation screen and 30-second recording interval).

October 18 (Monday) – Deployment of Teams to Stations in the Yucca Mountain Vicinity and to Station Nevada 1 for Tie-in

Teams were deployed to the following stations in the vicinity of Yucca Mountain: Claim, Black, Mile, 67TJS, and Wahomie. Because it is anticipated that contemporary strain rates near Yucca Mountain are slower than for the Hunter Mountain or Northern Death Valley fault zones, it was decided to conduct 24-hour surveys at stations Mile, 67TJS, and Wahomie in order to acquire more data. After securing badges at Mercury gate, signing in at the DOE Field Operations Center (FOC) and obtaining radios there, K. Snow and I drove to station Wahomie. We set up the equipment, covered the receiver and batteries with a tarp to protect them from any inclement weather, and left the station for breakdown of equipment 24 hours later on October 19. A supplementary fully-charged automobile battery was substituted for one of the battery power supply sources to assure that adequate power was available throughout the entire survey time period. The equipment was up and running by 10:46am.

After equipment was deployed, quick side trips were made to the Exploratory Studies Facility (ESF) and Trench 14 in the company of the NRC On-Site Licensing Representative, P. Justus. The ESF had been excavated by drill and blast techniques a total of 200 feet and was completely shot-creted except at the very end of the drift. An alcove was being excavated by drill and blast during our visit, so it was not possible to get close to the rock face currently being worked.

October 19 (Tuesday) – Breakdown of Stations Mile, 67TJS, and Wahomie and Reoccupation of Station Dante for Tie-in Survey

After obtaining my badge at Lathrop Wells gate, I drove to station Wahomie for removal of the GPS equipment. In a total elapsed time of 23 hours and 50 minutes during which the receiver was automatically recording data, 3327 records were recorded using up to 7 satellites at a time (15-degree elevation screen and 30-second recording interval).

B. Baker, G. Birchard, and I reoccupied station Dante to conduct a 1-hour long survey in order to tie-in two separate locations, separated by about 8m distance, at this station. This was done because the 1991 survey at Dante had been run on a USGS benchmark rather than on the reference marker (RM2) occupied in the current (1993) survey. This rapid reoccupation will make it possible to directly compare data from the 1991 and 1993 surveys once the more recent survey data are processed.

October 20 (Wednesday) - Acquisition of Maps and Return to Las Vegas

This day was spent acquiring additional maps and information to enable me to return to the region in late November and begin field reconnaissance investigations for the tectonics research project in the Black and Panamint Mountains. I also took a hasty driving tour of potential field reconnaissance areas.

October 21 (Thursday) - Trip to Yucca Mountain Site Area with P. Justus and W. Boyle

Status Meeting at FOC: After securing badges at Mercury gate and signing in at the FOC, P. Justus, W. Boyle and I attended the brief weekly DOE status meeting for contractors during which on-going activities for the Yucca Mountain project are discussed. Status reports on the following activities were provided: borehole; excavation; job package closeouts; ESF; and miscellaneous (Attachment 4). These weekly meetings are regularly attended by P. Justus in his capacity as NRC On-Site Licensing Representative.

Ghost Dance Fault Zone: After the status meeting, we drove to a new exposure of the Ghost Dance fault zone which was being mechanically cleared and cleaned for continued mapping by R. Spengler of the USGS. (R. Spengler was said to be on-site monitoring the progress of clearing the fault zone, but we missed him.) Across a width of artificially-exposed "road-cut" covering a total of about 71.5m (234 feet as determined by pacing) and an estimated height of less than 10m, the Tiva Canyon was seen to be strongly brecciated. (Tiva Canyon is the uppermost member of the Tertiary age Paintbrush Tuff; Topopah Spring, the potential repository horizon, is the lowermost member.) Both matrix-supported and clast-supported breccias occur, with calcite and siliceous vein fillings (possibly hydrothermal, but that remains to be determined) very common. Even though very strongly brecciated, the zone appears to be well-cemented and indurated at this location. Some mineral-lined vugs as large as 10-15cm also occur. The presence of extensive fracture fillings and veins may raise again the "Trench 14" issue of origin of such materials.

No units were exposed which would make it possible to determine if the zone exhibits Quaternary slip since the entire exposure was comprised by faulted Tiva Canyon of Tertiary age. Notwithstanding the apparent induration of the zone at this location, if it is to be avoided at repository depth because Quaternary displacement cannot be disproved, then the width of the zone may cause "avoidance problems" if it is as wide at repository depth as it appears to be at this exposure. There was not enough time to carefully examine the cleared exposure and determine whether caliche-cemented alluvial materials may comprise part of the "breccia" as the writer has observed at other localities near the Yucca Mountain site (e.g., at the Fran Ridge block test site). Because the exposure is on a relatively steep face, but one near the existing ground surface, this point needs to be considered in appraisal of fault-related brecciation at this location.

Fran Ridge Block Test: The next stop was the waste package environment thermal testing location at Fran Ridge. Excavation of a 3m x 3m x 4.5m block for the test is currently underway in this project, which is being managed by D. Wilder of Lawrence Livermore National Laboratory (LLNL). The block is in early stages of excavation at this time. A tentative schedule for completion of excavation and start of testing is shown in Attachment 5, the handout D. Wilder distributed during his presentation on the heater block test at the NWTRB meeting in Las Vegas on October 20. This attachment was obtained from P. Justus.

It was noted that most fractures in the soon-to-be-excavated block appear to be healed with calcite. J. Blink (LLNL) was present at the site and informed us that mesoscopic fractures were not observed to have formed in the block as a result of the controlled blasting being used for its excavation. Based on information obtained from J. Blink in response to my question about the possibility of blast-induced microfractures, no thin sections of tuff were cut prior to and after the controlled blasting being used to excavate the block to determine if microfracturing may have been induced. This would seem an oversight on the part of those planning the test since it is possible that interconnected microcracks could form flow pathways in the rock. This would have been a simple and quick test to conduct. "Breccias" occurring at this location appear to have formed by pedogenic cementation of coarse alluvial materials rather than as fault breccias.

Solitario Canyon Fault: A tentatively planned stop at new trenches excavated along the Solitario Canyon fault did not occur because of time constraints. These trenches are being mapped by A. Ramelli.

Useful Information Acquired: The ESF tunnel boring machine advance time line illustration, presented by DOE during the NWTRB meeting in Las Vegas on October 20 and obtained from W. Boyle, is attached to this report (Attachment 6). Also attached is the October 1993 NWTRB report (obtained from P. Justus) entitled, "Underground Exploration and Testing at Yucca Mountain - A Report to Congress and the Secretary of Energy" (Attachment 7).

PROBLEMS ENCOUNTERED:

No problems were encountered during any part of this trip.

RECOMMENDATIONS:

CNWRA involvement in this NRC-funded GPS project is already part of the Task 4 FY94 field efforts outlined in the CNWRA Tectonics Research Project Plan (Young and Stirewalt, 1993). The GPS effort, at the forefront of contemporary strain analysis, is essential for understanding how strain is partitioned in the region of study. Additional constraints for alternative regional tectonic models and structural models of faulting at Yucca Mountain should be provided by GPS data.

It is recommended that CNWRA become more actively involved in the GPS effort beyond FY94 - at least by providing assistance for annual data collection and possibly by placement of additional stations which would be linked to the existing network of B. Wernicke. Location of any new stations would be done in concert with NRC Research (G. Birchard) and B. Wernicke after additional planning discussions. If involvement is to occur beyond FY94, a supplementary research plan will be prepared for NRC review and approval as specified in the Tectonics

Research Plan (Young and Stirewalt, 1993). Continued involvement by CNWRA in the GPS effort would keep CNWRA and NRC in the forefront of tectonics investigations in the Yucca Mountain region and would assist with assessing tectonic models and related information to be provided for NRC review by DOE during prelicensing and licensing phases.

REFERENCES:

Holm, D.K., J.W. Geissman, and B. Wernicke. 1993. Tilt and rotation of the footwall of a major normal fault system-Paleomagnetism of the Black Mountains, Death Valley extended terrane, California. *GSA Bulletin* 105:10: 1373-1387.

Snow, J.K. and B. Wernicke. 1989. Uniqueness of geological correlations — An example from the Death Valley extended terrain. *GSA Bulletin* 101: 1351-1362.

Snow, J.K. and C. White. 1991. Listric normal faulting and synorogenic sedimentation, northern Cottonwood Mountains, Death Valley region, California. B.P. Wernicke, ed., Basin and Range extensional tectonics near the latitude of Las Vegas, Nevada. *GSA Memoir* 176: 413-445.

U.S. Nuclear Regulatory Commission. 1993. *Draft License Application Review Plan for review of license application for a geologic repository for spent nuclear fuel and high-level radioactive waste, Yucca Mountain site, Nevada.* NUREG 1323. Washington DC: U.S. Nuclear Regulatory Commission.

Young, S.R. and G.L. Stirewalt. 1993. Project plan for research on tectonic processes in the central Basin and Range region. Center for Nuclear Waste Regulatory Analyses report 0:4: 36.

AUTHOR: DATE: 8 November '93

Gerry L. Stirewalt

Gerry L. Stirewalt, Principal Geoscientist

CONCURRENCE: DATE: 11/12/93

H. Lawrence McKague

H. Lawrence McKague, Manager, Geologic Setting Element

DATE: 11/15/93

R G Baca for B. Sagar

Budhi Sagar, Technical Director

Attachments

B

Qty	Description	Origin	Manufacturer	Part #	Model #	Serial #
1	9V CELL	USA			9V CELL	
1	AC ADAPTER	JAPAN	TOSHIBA	PA8713U	T1000SE	
1	ANTENNA	USA	TRIMBLE	14532-00	4000SST	3006A00029
1	ANTENNA BAG	USA	TRIMBLE		4000SST	
1	ANTENNA CABLE 10M	USA	TRIMBLE	14553-00		90-02-035
1	ANTENNA CABLE 30M	USA	TRIMBLE	14551-00		90-04-011
1	AUX PWR CABLE	USA	TOSHIBA			
1	BAROMETER	USA	AIR		AIR-HB-1A	921024
1	BATT. CHARGER	USA	XENOTRONIX		8103F1217A0	
1	BATT. PWR CABLE	USA	TRIMBLE	14555REVA	LM8843	
1	BATTERY A	GERM	SONNENSCHE	G2598	DRYFIT A200	
1	BATTERY B	GERM	SONNENSCHE		DRYFIT A200	
1	BATTERY PACK	JAPAN	TOSHIBA	PA8712U	T1000SE	
1	BATTERY PACK	JAPAN	TOSHIBA	PA8712U	T1000SE	
1	CARRYING CASE	JAPAN	TARGUS			
1	COMP/BATT CABLE	USA	UNAVCO		T1000SE	
1	COMPASS	SWED	SILVA		7NL	
1	COMPUTER	JAPAN	TOSHIBA	PA8003U	T1000SE	8046028
2	D CELLS	USA			D CELL	
1	DOWNLOAD CABLE	USA	UNAVCO		FUSED	
1	ELEC. TAPE	USA				
1	FLASHLIGHT	THAIL	RAYOVAC		WORKHORSE	
5	FUSES	USA	UNAVCO			
1	JUMPER CABLES	USA				
1	MULTIMETER	JAPAN	BECKMAN		DM78	20108814
1	OPERATOR MANUAL	JAPAN	TOSHIBA		T1000SE	
1	PLUMB BOB	USA	SOKKIA		16	
3	SAND BAGS	USA				
3	SOFTWARE DISKS	JAPAN				
1	SURGE SUPPRESR.	USA	TRIPP LITE		IB4	
1	SURVEY TAPE	USA				
1	TAPE MEASURE	USA	STANLEY	33-215	3.5M/12'	
1	TARPOULAN	USA				
1	THERMOMETER	USA				
1	TOOL BAG	USA	UNAVCO			
1	TRANSPORT CASE	USA	HARDIGG	AL2221050S		
1	TRANSPORT CASE	USA	DOSKOCIL	62200		
1	TRIBRACH	SWITZ	WILD	506-289	GDF22	
1	TRIBRACH ADAPTER	USA	SECO	207		

total lbs 73.5

RX

Qty.	Description	Origin	Manufacturer	Part #	Model #	Serial #
1	DOWNLOAD CABLE 5PIN	USA	TRIMBLE	18826	4000SSE	
1	GPS RECEIVER	USA	TRIMBLE	18290-51	4000SSE	33C7A03466
1	LOG BOOK	USA	DARLING	310	RITE IN THE	
1	OPERATOR MANUAL	USA	TRIMBLE	REV A	4000SSE	
1	TRANSPORT CASE	USA	KINETICS		718	

total lbs 16

T

Qty.	Description	Origin	Manufacturer	Part #	Model #	Serial #
1	HEIGHT STICK	USA	TRIMBLE	18182		
1	TRIPOD	SWITZ	WILD		GST20	
1	TRIPOD CASE	USA	TUFFPAK	TP0741		

total lbs 26

GPS Daily Observation Log
UNAVCO (University NAVSTAR Consortium)

Yucca Mountain 1993

UCAR, Boulder, CO., USA

Station Name: ______________________ 4-Char ID: ____________
Location: ______________________ City: ____________
Monument Inscription: ______________________ Country: USA

System Number ____________

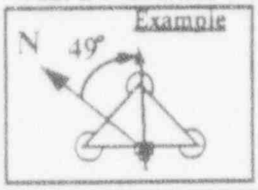
	TYPE	MODEL	SERIAL No.
Receiver	Trimble	4000 SSE	
Antenna	Trimble	SST	
Tribrach	Wild		

Operators: ____________ Agencies: ____________

Receiver Software & Version: ____________
Cable Length: ____________ Collection Rate: ______ Sec

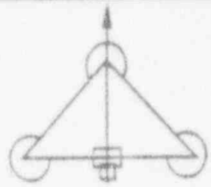
What is orientation of eye piece with respect to North?

Example



Draw North arrow

Circle one:
TRUE MAGNETIC
Write number of degrees



Antenna Ht. Above Mark in Meters

Slant Height ☐ Vertical Height ☐

Notch No.	Before	After
1		
2		
3		
Avg.		

Ht. in inches ______ in= ______ m
(0.0254 m/in) or (39.37 in/m)
Ht. put into receiver ____________
Crosshairs on target? ____________
Plumb bob check? ______ ______
Magnetic declination ____________
Compass reading ____________ ☐ True
Compass type ____________ ☐ Mag.

Observation Times:	UTC Time	UTC Date	UTC Day
Scheduled Start Time			
Scheduled End Time			
Actual Start Time			
Actual End Time			
Daily Session Number		☐ Power Failure	

Meteorological Data:

Time (UTC)	Pressure (mb)	Dry Bulb (C)	Wet Bulb (C)	Comments

Receiver Solution. *Source: Best 3D Position from .MES file.* *Other* ____________
Best PDOP ______ Latitude ____________ Longitude ____________ Height ______ m

Download Information: Compare disks: ☐ Download software version ____________

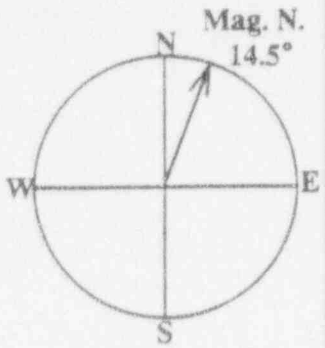
Disk	Disk #	Filename	.DAT	.EPH	.ION	.MES	.DAT file size	.MES file size
	/							
	/							
	/							
	/							

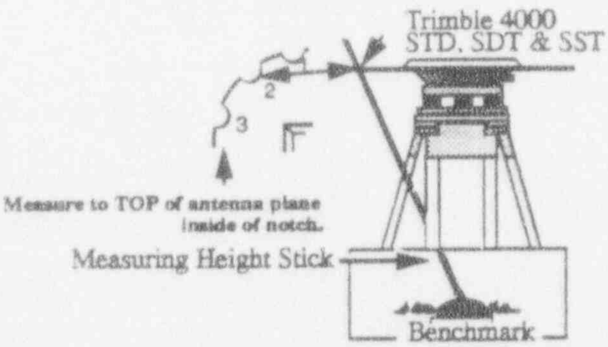
DID ANYTHING ABNORMAL OR UNUSUAL OCCUR? ☐ YES ☐ NO

Time (UTC)	*Comments and Significant Problems:* ☐ Check if additional sheets attached.

Station ID ________ UTC Start Date ____________ UTC Start Day ________ Session No. ________

Antenna Setup & Height Measurement:
(Sketch setup if different from figure. If measuring a vertical height show exactly what you measured.)





Location Diagram:
(indicate mark you set up on in relation to local surroundings)

Rubbing or Photo of Monument: *Indicate the exact point that the instrument was centered over and include a North arrow. (If rubbing is hard to read add a sketch of the monument).*

Station ID __________ UTC Start Date ______________ UTC Start Day _________ Session No. ___________

ATTACHMENT 3

System Number:

UNAVCO

GPS Station Description

University Navstar Consortium

UCAR, Boulder, CO., USA

Station Name: ______ 4-Char ID: ______ Station ID #: ______

Location: ______ Country: ______

Observing Monument Inscription: ______ Project: Yucca Mtn.

Approximate Geodetic Coordinates:

Latitude: ______ Datum ______ Magnetic Declination 14.5° E

Longitude: ______ Source of Position ______ Rate & Direction of Change ______

Height: ______ Source of Declination USGS

Site Personnel:

Name	Agency

Access Notes:

Location Diagram:

Rubbing or Photo of Monument: Indicate the exact point that the instrument was centered over and include a North arrow.

Station ______ UTC Start Date ______ UTC Start Day ______

ATTACHMENT 4

BOREHOLE ACTIVITIES

TEST ACTIVITY	JOB PACKAGE/WORK PROGRAM/TEST PLANNING	SCHEDULE INFORMATION	COMMENTS ON STATUS
NRG-2, NRG-2A, NRG-2B, NRG-3, NRG-4, NRG-5, NRG-6	TPP 92-1		No current activity. Geophysical logging partially (?) complete. Plans in progress to pull casing and run video logs in NRG-2A and NRG-2B.
NRG-7 BOREHOLE	JP TBD WP TBD TPP 92-1	Pad accepted 10/01/93.	Drilling equipment fully mobilized. Waiting on work authorization expected 10/21/93. Double shifts planned.
* ADDITIONAL DRILLING & TRENCHING IN VICINITY OF NRG-2	Unknown	Environmental surveys started 10/12/93.	Environmental survey in progress.
* UZ-14	JP 92-17 WP 93-9 TPP T92-16	Additional grouting scheduled for 10/21/93.	Core depth 1422.1, ream depth 1421.6. Currently initiating sealing of second water-bearing zone.
* UZ-16	JP 92-3 WP 92-03 TPP T92-02	Drilling completed 03/10/93.	Removal of lodged packer still in progress using CME 850. Camera run needs to be scheduled after removal of packer.
* SD-12 DRILL PAD & ACCESS ROAD	JP 93-13 WP N/A TPP T93-9	Site preparation started 10/01/93.	Pad excavation in progress. Rock cropping out on the southwest corner is difficult to rip; FCR for blasting expected to be issued 10/21/93.

BOREHOLE ACTIVITIES				
	TEST ACTIVITY	**JOB PACKAGE/WORK PROGRAM/TEST PLANNING**	**SCHEDULE INFORMATION**	**COMMENTS ON STATUS**
*	WT-2	JP N/A WP 93-17 TPP N/A	New logging by USGS scheduled for 10/21/93. Road improvement for seismic survey to start 10/21/93.	Standard geophysical logs were run 10/18/93.
*	C-WELL TESTING	JP 93-11 WP 93-10 TPP 92-09	Resumed soil remediation on 10/05/93. Soil remediation in progress for unknown duration. Plan to backfill all excavations about the end of October.	(Environmental Field Coordinator to status.)

EXCAVATION ACTIVITIES			
TEST ACTIVITY	**JOB PACKAGE/WORK PROGRAM**	**SCHEDULE INFORMATION**	**COMMENTS ON STATUS**
* QUATERNARY FAULTING W/IN 100 KM: BARE MTN. TRENCHES	TPP T92-17(0)	Completed excavation of BMTP-8, BMTP-9 and BMT-1 on 09/29/93.	Waiting on mapping to start.
* GHOST DANCE FAULT EXCAVATION	TPP T93-06	Excavation completed 09/22/93. Cleaning started 09/27/93.	REECo installed gauges on water hoses to monitor usage during cleaning. Cleaning of east pavement underway. NOTE R. Spengler here this week apparently
* TRENCHES A-1 & MWV-T3 (ALICE RIDGE)	JP 92-05	FY94 - TBD.	(SAIC status)

JOB PACKAGE CLOSEOUTS			
TEST ACTIVITY	**JOB PACKAGE/WORK PROGRAM**	**SCHEDULE INFORMATION**	**COMMENTS ON STATUS**
SOIL & ROCK PROPERTIES PHASE II TEST PITS	JP 92-8	Record submittals past due. Due date 09/27/93.	No change since last week. Field Verification Plan, water use records, and as-built drawings still required to complete records package.
SOIL & ROCK PROPERTIES NORTH PORTAL	JP 92-02	All record submittals due by 10/04/93.	No change since last week. Need remaining RSN and REECo records listed in 08/16/93 ltr. from Winn Wilson to complete.
NEUTRON-ACCESS BOREHOLES	JP-91	All recor[illegible]mittals due by 10[illegible]5/93.	No change since last week. Need remaining REECo, RSN, and Drilling Support records listed in 09/09/93 ltr. from Winn Wilson to complete.
NRG-6 ROAD & PAD	JP 92-10	Record submittals past due. Due date 01/17/93. Due date extended to 04/30/93 (Kopatich to Wilson ltr. dated 04/01/93.)	Need some water use records to complete records package. Records package table of contents being prepared.
UZ-16 ROAD & PAD	JP 92-04	Record submittals past due. Due date 05/18/93.	Records package table of contents being prepared.
NRG-4 ROAD & PAD	JP 93-02	Record submittals past due. Due date 08/15/93.	Reminder memo sent 06/18/93. Records are being submitted.
NRG-5 ROAD & PAD	JP 93-03	Record submittals past due. Due date 06/14/93.	Some items received. Still need balance of RSN records listed in 07/20/93 ltr. from Winn Wilson to Kopatich.

JOB PACKAGE CLOSEOUTS

TEST ACTIVITY	JOB PACKAGE/WORK PROGRAM	SCHEDULE INFORMATION	COMMENTS ON STATUS
NRG-7 ROAD & PAD	JP 93-14	All records submittals due by 11/30/93.	Road and pad completed and accepted on 10/01/93. Reminder memo sent out 10/12/93.

MISCELLANEOUS ACTIVITIES			
TEST ACTIVITY	**JOB PACKAGE/WORK PROGRAM/TEST PLANNING**	**SCHEDULE INFORMATION**	**COMMENTS ON STATUS**
* ENGINEERED BARRIER: LARGE BLOCK TEST	TPP T-93-3 JP 93-10	Start date: 08/25/93.	(LANL to status) - Leveling blast "next week"

ESF ACTIVITIES				
	TEST NAME	**JOB PACKAGE/WORK PROGRAM/TEST PLANNING**	**SCHEDULE INFORMATION**	**COMMENTS ON STATUS**
*	UNDERGROUND GEOLOGIC MAPPING	JP 92-20A TPP 92-10	04/08/93 (start) Started alcove 10/04/93. Mapped alcove from 0+15 to 0+27 on 10/12/93.	(LANL to status)
*	CONSTRUCTION MONITORING IN THE STARTER TUNNEL	JP 92-20D TPP T-92-2	04/08/93 (start)	Ongoing. (LANL will status)
*	CONSOLIDATED SAMPLING IN THE STARTER TUNNEL	JP 92-20C TPP 92-14	05/27/93 (start)	Ongoing
*	PERCHED WATER TEST IN ESF	JP 92-20B TPP 92-11	04/08/93 (start)	This is a contingency test to be performed only if perched water is encountered.
*	HYDRO CHEMISTRY TESTING	TPP 92-12	Prototype testing performed 09/23/93.	LANL status

c:\reports\boreplus

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

NUCLEAR WASTE TECHNICAL REVIEW BOARD FULL BOARD MEETING

SUBJECT: WASTE PACKAGE ENVIRONMENT THERMAL TESTING UPDATE

PRESENTER: DALE G. WILDER

PRESENTER'S TITLE AND ORGANIZATION: TECHNICAL AREA LEADER
LAWRENCE LIVERMORE NATIONAL LABORATORY
LIVERMORE, CALIFORNIA

PRESENTER'S TELEPHONE NUMBER: (510) 422-6908

LAS VEGAS, NEVADA
OCTOBER 19-20, 1993

ATTACHMENT 5

We are moving dirt

Test Strategy

Scale	Purpose
Lab Scale Core - 1 ft. hours to days (some long-term)	Property Measurements Matrix Processes Single-Fracture Processes Limited Model Testing
Block Scale 1 ft. to 3-5 m.	Multiple-Fracture Processes Fracture Interconnectivity Phenomena Coupled Processes

In Situ Heater Tests

ESF Tests (up to few 100 ft.)	Site characterization *In Situ* Hydrothermal/Geochemical/ Geomechanical Responses
Large Scale	Scaling Effects, Natural Heterogeneity Impacts
Repository Scale Monitoring	Performance

In situ Heater Tests Can Test Fundamental Hypotheses

(1) Conditions where heat conduction dominates heat flow

(2) Whether above-boiling temperatures remove all mobile liquid water

(3) Whether fracture density and connectivity are sufficient for rock dry-out

(4) Whether re-wetting significantly lags the end of boiling

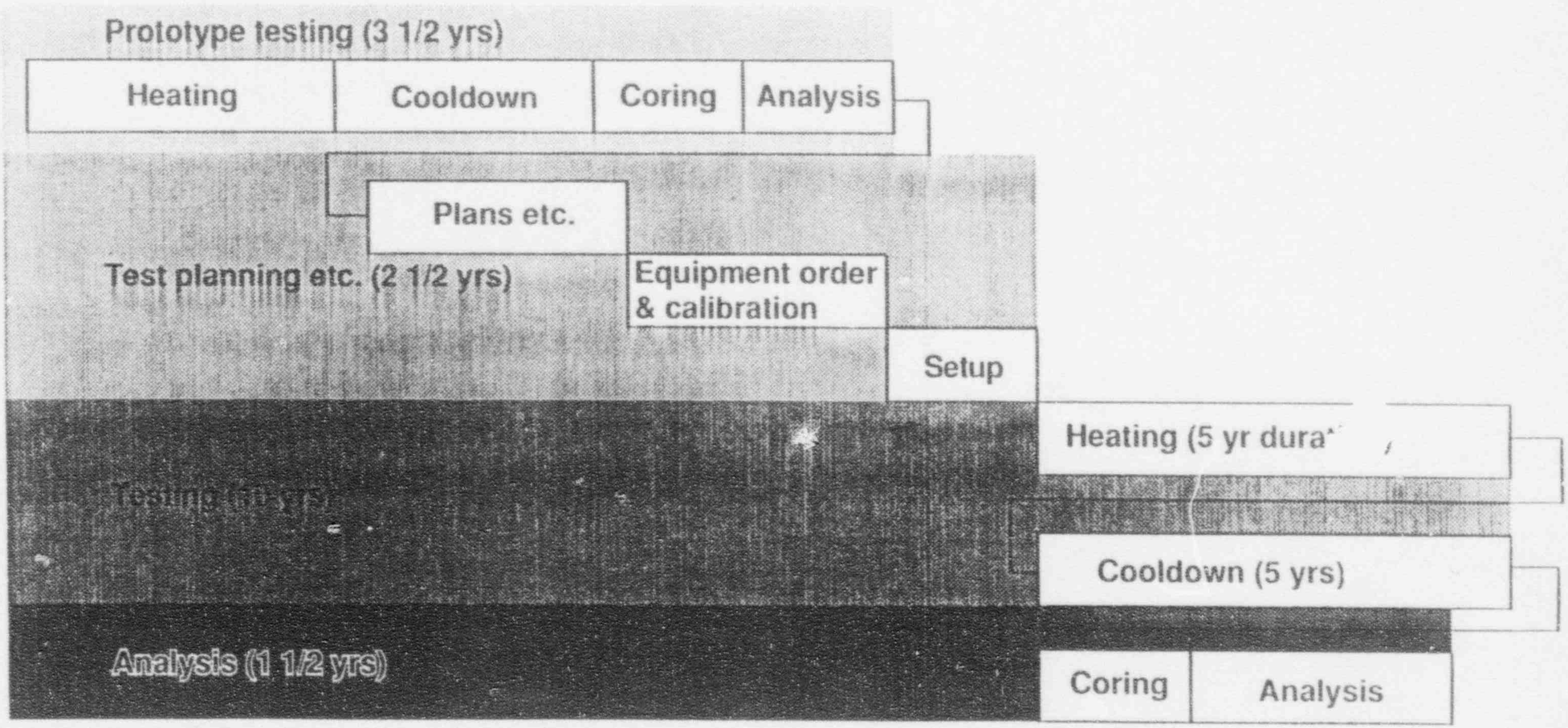
(5) Conditions where large-scale, buoyant, gas-phase convection may dominate

The large block test will provide valuable information pertaining to all five hypotheses tests, particularly to hypotheses 2, 3,and 4

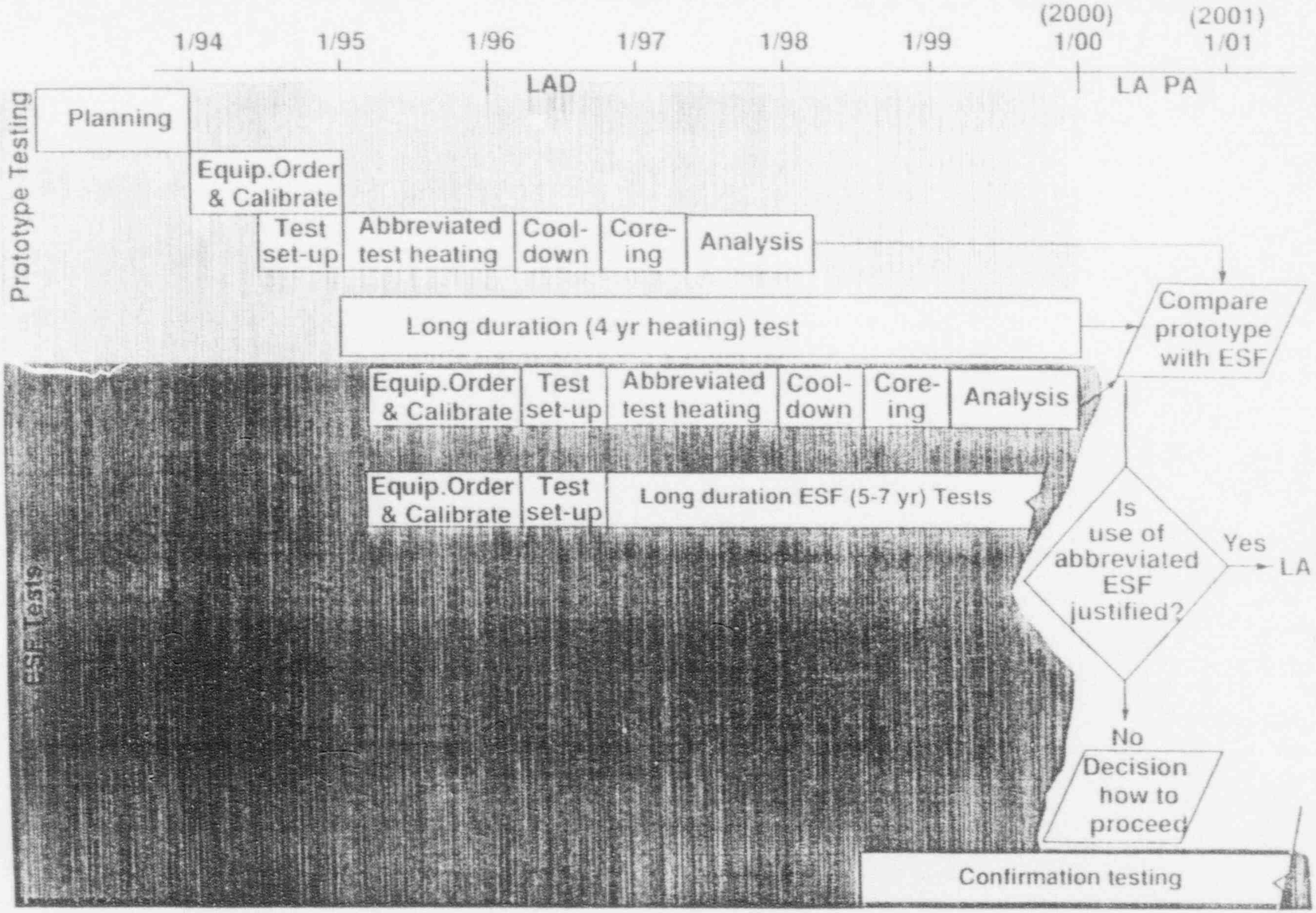
Criteria for Design of Waste Package Environment Tests

- Volume of the dry-out zone
  - G-Tunnel ~0.75 m
  - Small percentage of fractures responsible for majority of flow
- Peak rock temperatures
  - Above 200 degrees can have phase transition
- Velocity of dry-out front
  - Lab tests of up to one-year duration required
- Size and duration of condensate zone
- Time rate of change of temperature

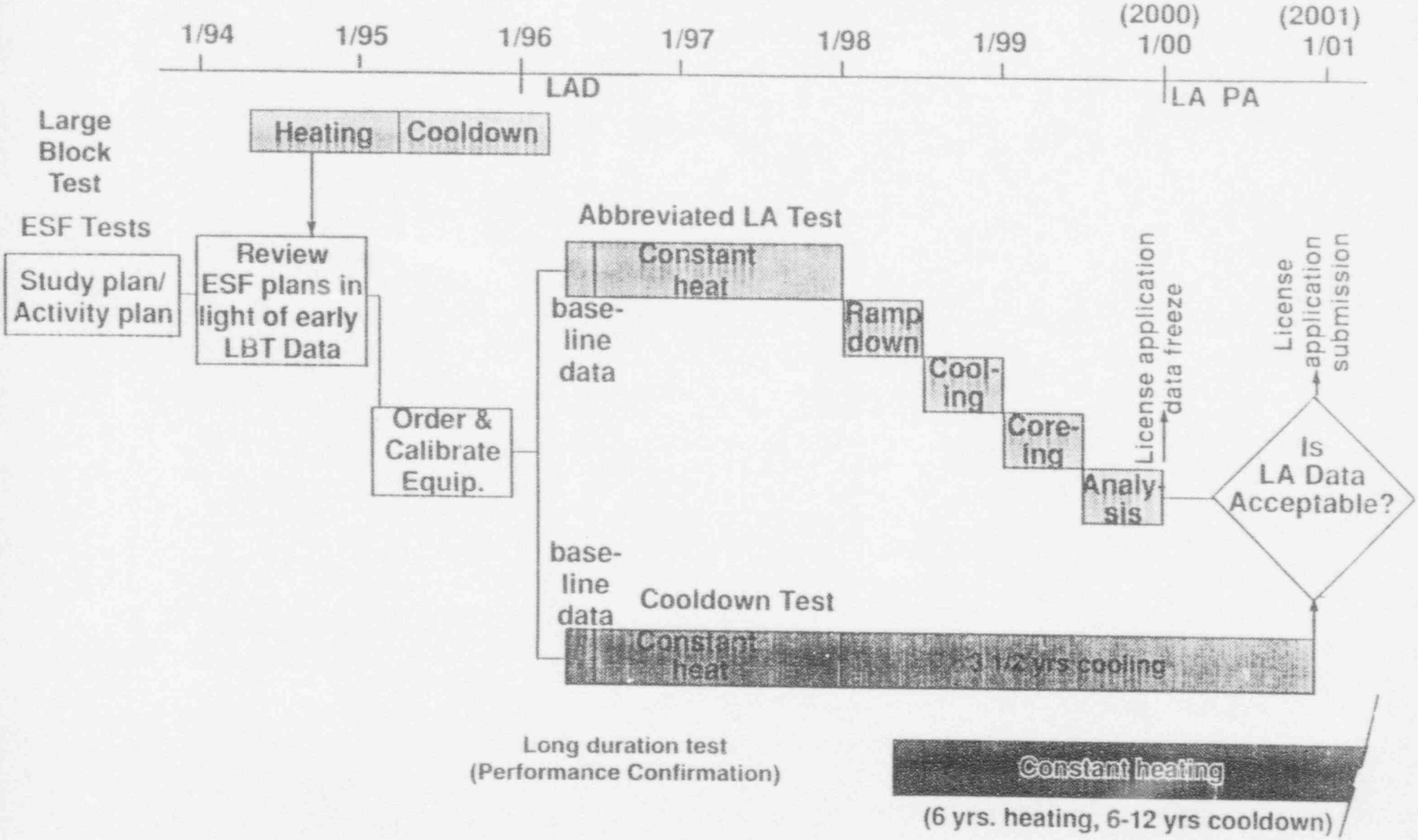
Ideal Strategy



Strategy with Off-Block Prototype Testing



Strategy Using Large Block Test



(BEST AVAILABLE COPY)

Issues Requiring Testing Before ESF Testing

- Validation test independent of those used for characterization (property values, etc.) data, and developing or testing models

  Developing and testing require "tweaking knobs" in the models to understand physics. Validation test design relies on scoping calculations; therefore, the physics must be appropriate prior to testing

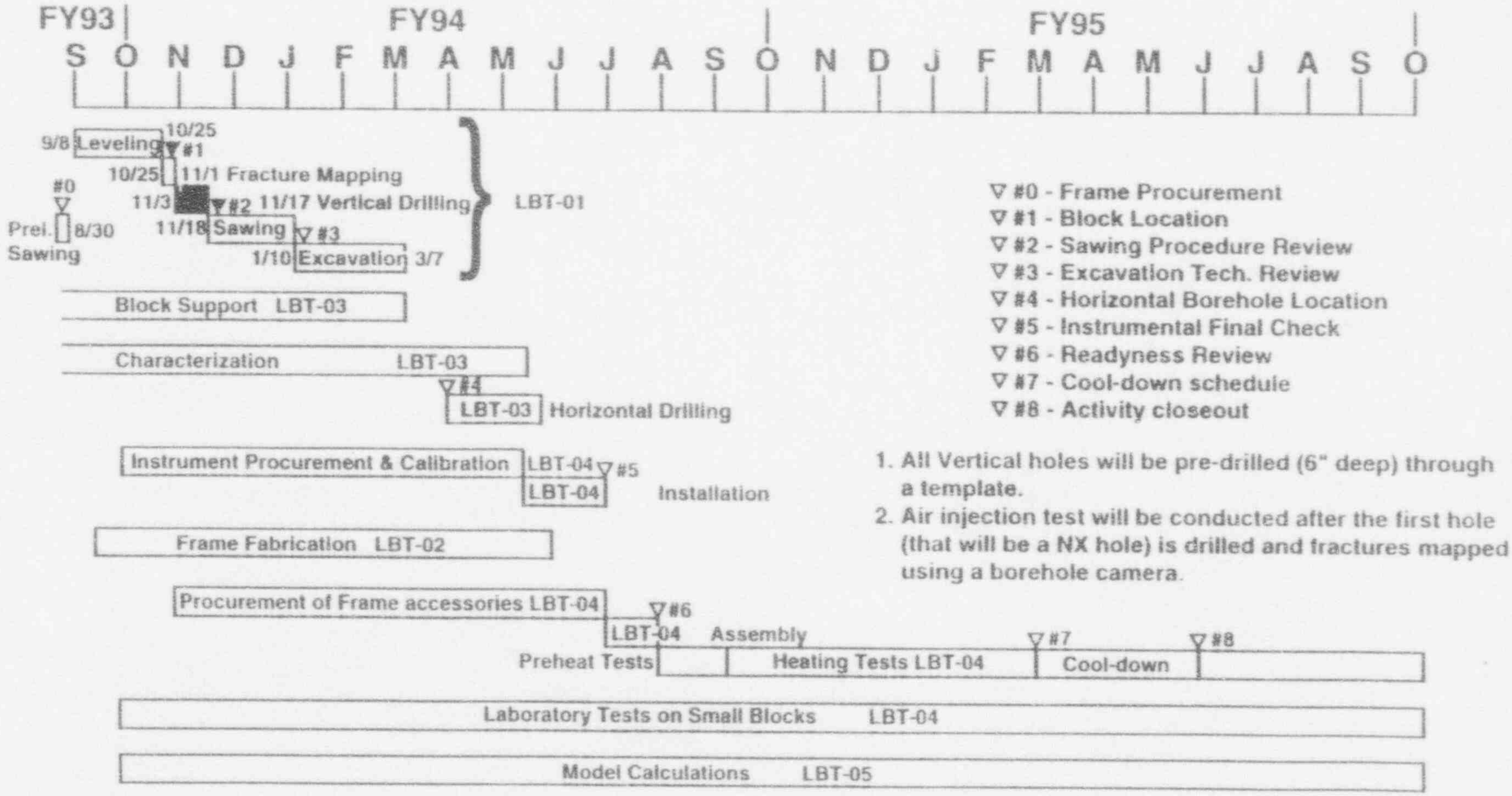
- Early decisions based on model predictions (e.g., thermal loading, MPC, emplacement strategy) require that processes important to the outcomes be incorporated into models. The models have not been demonstrated adequately

- ESF test planning

  - Confidence in models used for planning of ESF tests
  - Instrument and technique evaluation prior to ESF test
  - Evaluation of scaling effects

Large Block Test at Fran Ridge

(photo)



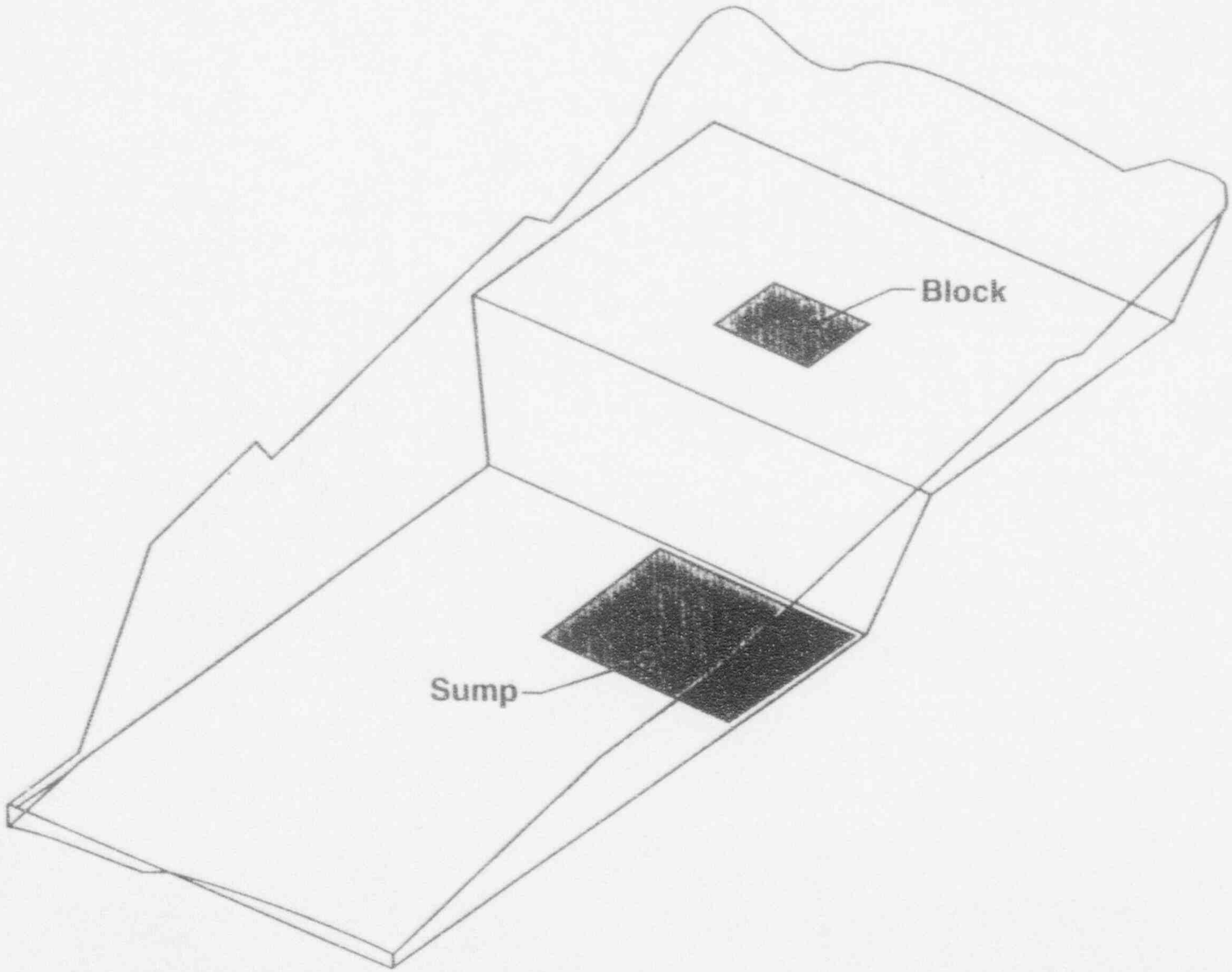
1. All Vertical holes will be pre-drilled (6" deep) through a template.
2. Air injection test will be conducted after the first hole (that will be a NX hole) is drilled and fractures mapped using a borehole camera.

DCLLNLDW CDR4 125 NWTRB/10 19/20 93

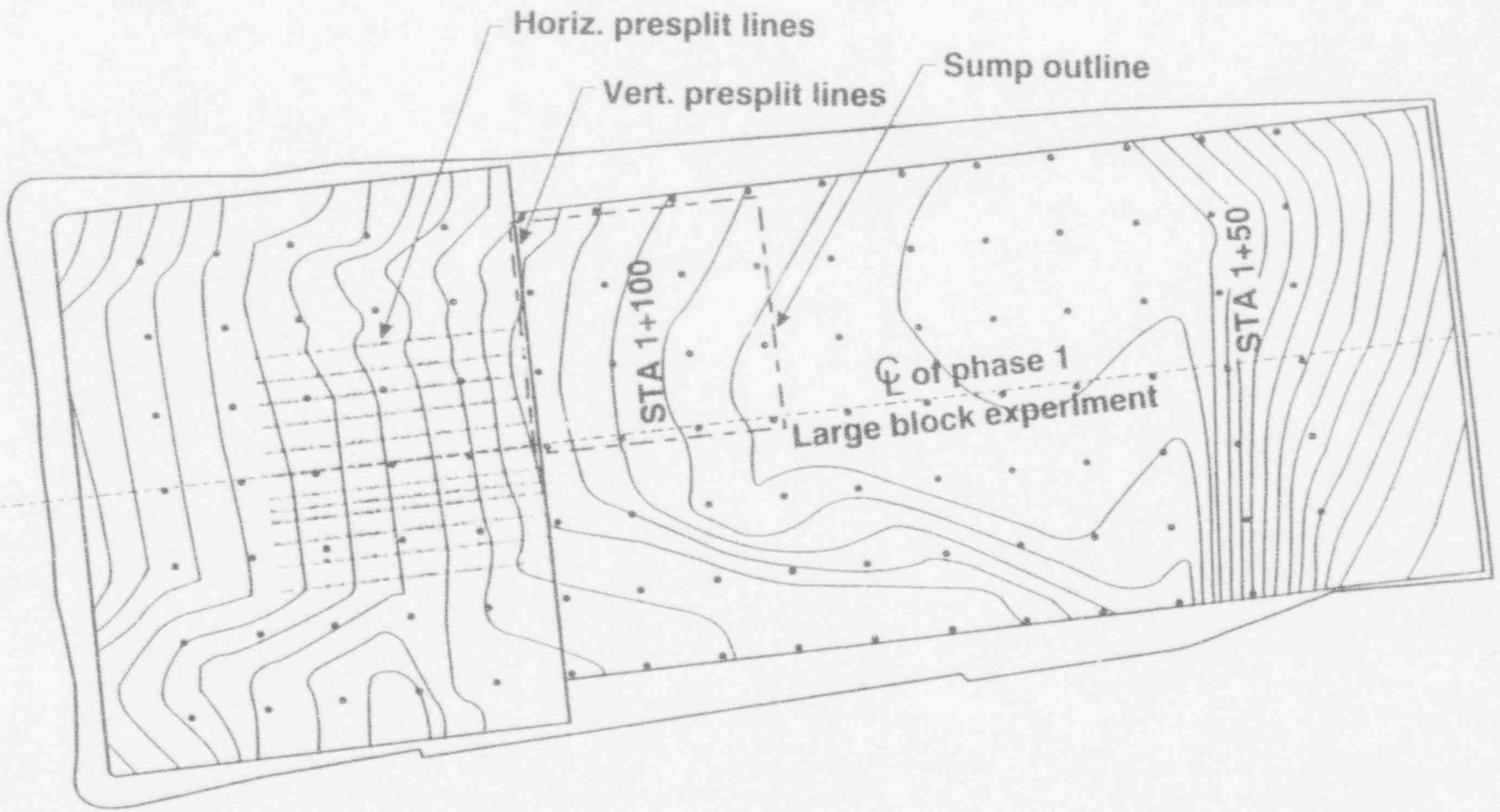
Large Block Test Status

- Planning offsite
- Excavation started
- Drilling and testing mid-October
- Cutting planned for mid-November
- Planning documents progressing
- Test-frame contract awarded

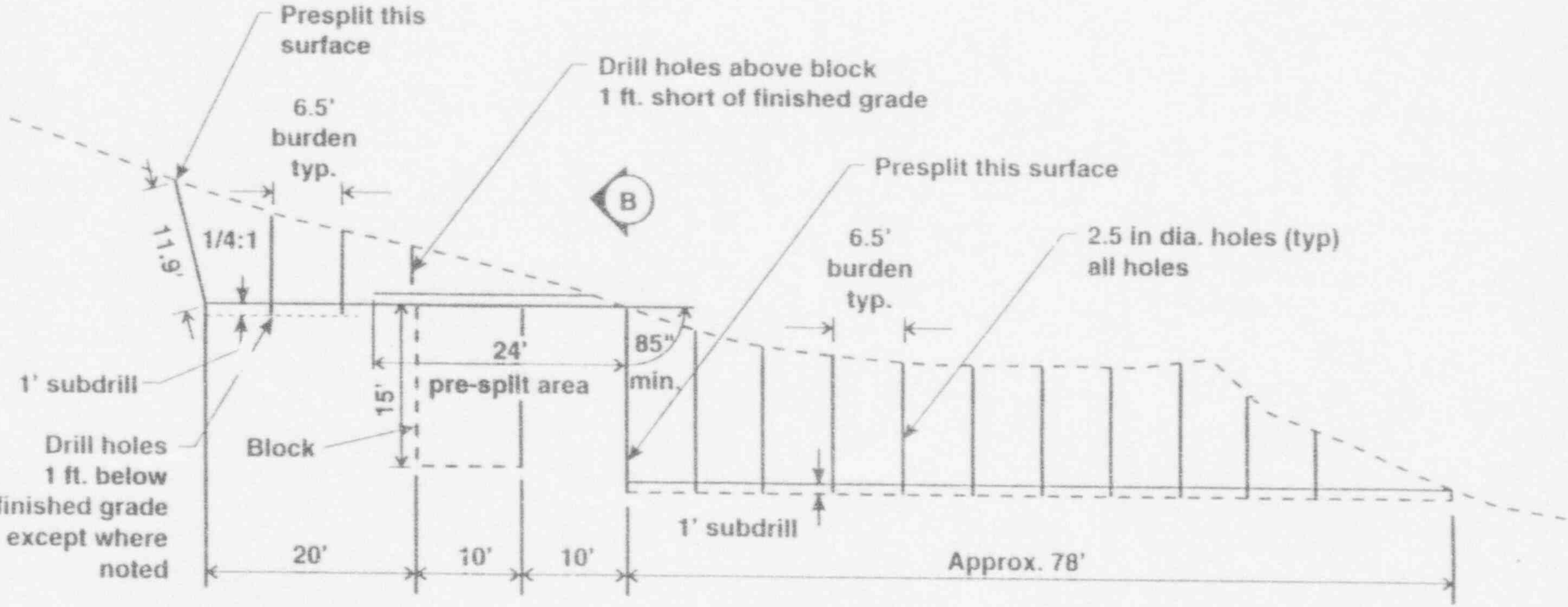
Benching for Large Block Test



Excavation Plan Large Block Test



Cross Section of Excavation Plan



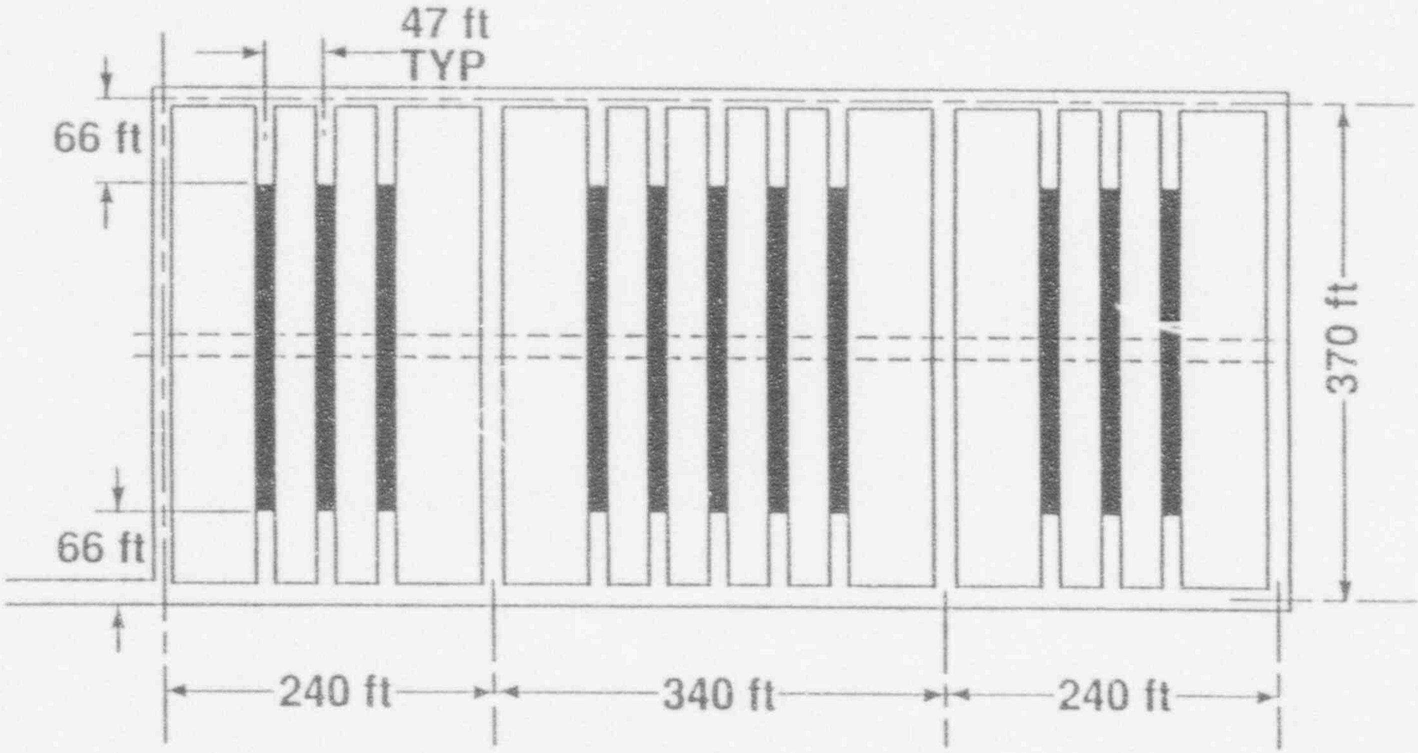
EXCLBTDW2 125 NWTRB CDR/10-19/20-93

Photo

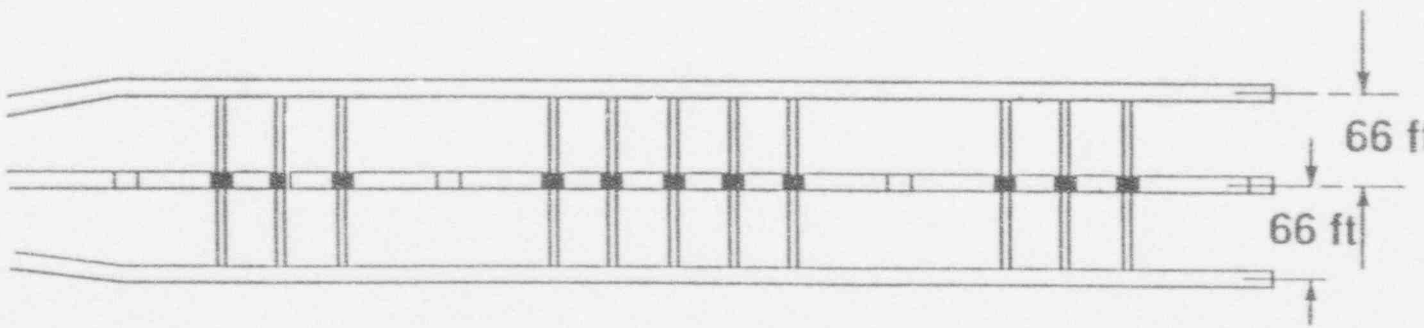
DCLLNLDW31 125 NWTRB/10 19/20 93

Videotape

Layout of ESF Tests



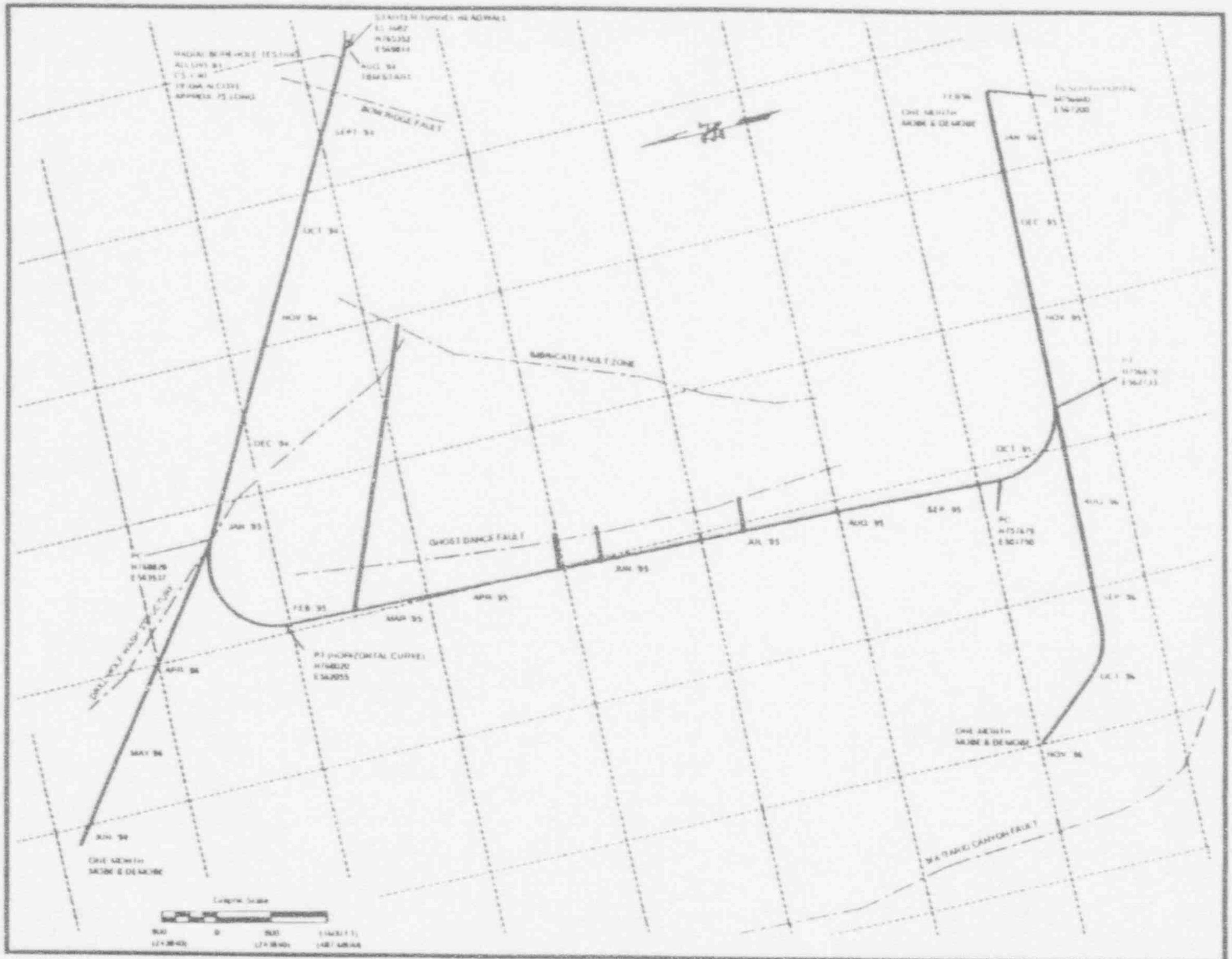
Plan



Cross Section

ATTACHMENT 6

Exploratory Studies Facility Tunnel Boring Machine Advance Time Line Illustration



As of 10-1-93

LEGEND

FAULT ZONE

RAMP CONFIGURATION

REFERENCE GRID

BOREHOLE LOCATION

COMMENTS

NORTH PORTAL BOX CUT FACE AT CS 0+00

ALCOVE #1 APPROXIMATELY LOCATED AT CS 1+40

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

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

STARTER TUNNEL CONFIGURATION AND AZIMUTH FOR THE FIRST 200 FT (60.960 m) 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

FAULT TRACE LOCATIONS EXCEPT FOR THE BOW RIDGE FAULT ARE APPROXIMATIONS BASED ON AT DEPTH PROJECTIONS OF INFORMATION FOR 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

SCHEDULE BASED ON EXCAVATION RATE OF 300 FEET WEEK

CYMUZESF3.125 NWTRB/10 19/20 93

ATTACHMENT 7

Underground Exploration and Testing at Yucca Mountain

A Report to Congress and the Secretary of Energy

Nuclear Waste Technical Review Board
October 1993

Nuclear Waste Technical Review Board

Table of Contents

List of Figures

This report is the eighth in a series of reports by the Nuclear Waste Technical Review Board. Reports are available from the Government Printing Office, Washington, D.C., or from the Board's office in Arlington, Virginia.

Executive Summary

Underground exploration and testing are major components of the DOE's site-characterization efforts at Yucca Mountain, Nevada. During the past four years, the DOE's plans for exploration and testing in an underground facility have evolved substantially, and many improvements have been made. The DOE's current program involves extensive tunneling throughout the geologic block at Yucca Mountain with the goal of gaining visual access to the complex geology at the site. It is especially important to thoroughly understand the character and extent of the faults that cross the site, as well as the site's hydrogeology and geochemistry. Once tunnels have been excavated, scientists also will be able to initiate important tests, which are necessary to assess how the natural and engineered barriers will perform under conditions similar to those in a potential repository for hot spent fuel and high-level waste. Data gathered during these tests will be used to evaluate site suitability, to predict long-term performance of the entire repository system, and to support a license application — should the site prove suitable.

In this report, the Board reviews the status of the underground exploration and testing program. In addition to a number of detailed recommendations, the Board makes three general recommendations, which are reviewed below. The Board would like to emphasize that all recommendations can and should be implemented without slowing the momentum of important site-characterization activities now under way at Yucca Mountain.

The Board concurs with the overall objectives established by the DOE for underground exploration and testing at Yucca Mountain and supports many of the changes that have been made to the design of the facility. However, the Board remains concerned that, because of past delays in initiating underground exploration and attempts to comply with overly optimistic schedules, the DOE is making important technical decisions about the design and approach to excavation of the exploratory facility without sufficient analysis. Schedules have been compressed, and until recently the DOE had planned for multiple excavation operations from a single portal and simultaneous testing activities, which the Board believes would have extended, rather than shortened, program schedules and increased costs. The Board supports the DOE's recent decision to modify this approach by eliminating competing activities during excavation of the initial underground loop. Once this portal-to-portal loop has been completed, tunneling off the loop to fault zones, in the core test area, and in the Calico Hills can begin, and important testing initiated.

The Board believes, however, that the Yucca Mountain project lacks an overall strategy for exploration and testing. To better achieve the objectives of the underground exploration and testing program, *the Board recommends that the DOE develop a comprehensive strategy that integrates exploration and testing priorities with the design and excavation approach for the exploratory facility.*

This strategy should be based on specific intermediate goals and be consistent with the scientific priorities of site characterization, realistic funding expectations, and the efficient development of the underground exploratory facility. With such a strategy, the DOE could simplify what is still an overdesigned facility, which includes excessive test support facilities and utilities.

Thermal testing should be an important component in any comprehensive strategy for exploration and testing at Yucca Mountain. *The Board recommends the resumption of underground thermal testing as soon as possible.* Since testing in the core test area is not scheduled to begin until early 1998, the DOE should consider reinitiating underground thermal testing outside the repository area. This will allow the DOE to establish a continuous testing program for the development of instrumentation and procedures and to gain as much testing experience as possible *prior* to initiating testing in the core test area.

The Board believes that the excavation of the exploratory facility could be accomplished more quickly and at less cost if the tunnels and support facilities were designed only to meet the needs of exploration and testing. For example, after the portal-to-portal loop has been completed, excavation of tunnels off the loop and in the core test area can begin using a 16- to 18-ft-diameter tunnel boring machine. The design of the core test area, where critical thermal testing will be conducted, should be simplified to allow excavation using a full-face tunnel boring machine. Although extensive tunneling is required, the DOE should continue to reduce the extent of surface and subsurface facilities and utilities to reflect the revised sequential excavation plan and the specific needs of the exploration and testing program.

If the Yucca Mountain site proves suitable and is licensed for construction, the exploratory facility is to be integrated into the repository design. Therefore, the design of the exploratory facility should remain as compatible as possible with potential repository designs. The DOE's recent proposal to reduce tunnel gradients in the exploratory facility makes it more compatible with existing repository designs.

The Board recognizes the complex regulatory and oversight constraints facing the U.S. high-level waste program and the challenges inherent in managing such a large, first-of-a-kind scientific and engineering project. However, the Board believes that a wealth of industry expertise and experience exists from which the DOE could draw more effectively. To assist program managers and to take maximum advantage of existing experience in the underground construction industry, the *Board recommends that* — as is common practice on large construction projects — *the DOE establish a geoengineering board with expertise in the* *engineering, construction, and management of large underground projects.* Members should be nationally known and their selection based on past experience serving on similar boards for projects of commensurate complexity. This geoengineering board would meet with Yucca Mountain management, staff, and contractors on a regular basis to review detailed decisions *early on* — when they are first being made — and to provide guidance on improving the management of the design and excavation of the exploratory facility.

As it stated in its March 1993 *Special Report*, the overall civilian waste management program is large and diffuse, and specific responsibilities are unclear. The Board finds this to be true as well at the Yucca Mountain project level. Even though site characterization at Yucca Mountain is not a routine construction project, the DOE should place greater emphasis on developing a more efficient system for managing the exploratory facility design and construction. In general, decisions do not reflect typical industry practice; its contracts do not include incentives for minimizing costs and meeting schedules; and the DOE has contracted for its own tunnel boring machine, rather than holding the contractor responsible for selecting and purchasing its own equipment.

Finally, many institutions, including Congress, have expressed the concern that a disproportionate share of the funding available for the nation's nuclear waste management program is being directed to overhead and infrastructure. The Board is concerned that this is leaving limited funds for important scientific work, including underground exploration and testing. For example, recently the DOE cited funding, rather than technical grounds, as a possible reason to forgo excavation of the Calico Hills unit. And funding choices may affect when important underground thermal testing will be reinitiated, or when the contractor will begin acquisition of another tunnel boring machine. The Board strongly supports the Secretary of Energy's decision to review the financial aspects of the civilian radioactive waste management program and hopes that this review will lead to a more efficient and cost-effective exploration and testing program.

Introduction

The Nuclear Waste Technical Review Board (the Board) was created in the Nuclear Waste Policy Amendments Act of 1987. As an independent agency within the executive branch, the Board is charged with evaluating the scientific and technical aspects of the Department of Energy's (DOE) program to manage the disposal of the nation's spent nuclear fuel and high-level defense waste. The Board reports its findings and recommendations to Congress and the Secretary of Energy at least twice each year.

Since its inception in 1989, the Board has followed closely the efforts of the DOE Office of Civilian Radioactive Waste Management (OCRWM) to design and implement this program. Characterization and assessment of the site at Yucca Mountain, Nevada, for its suitability for developing a permanent repository for this waste is a major component of the DOE's program. If the site at Yucca Mountain is found suitable and is licensed by the Nuclear Regulatory Commission for repository development, a complex of tunnels would be excavated in the mountain.

To determine the suitability of the site and gather the data necessary to design the proposed repository, the DOE must undertake an extensive program of surface-based and underground exploration and testing. Surface-based activities have been under way at the site for some time. Preparations for underground exploration and testing have just begun. These underground activities are the main focus of this report.

Background

In March 1993, the Board published a *Special Report* (NWTRB, March 1993) to the Congress and the Secretary of Energy. That report outlined three critical concerns that have affected the technical components of the DOE's civilian radioactive waste management program: (1) the program's overly optimistic schedules; (2) the need for a well-integrated overall waste management plan that includes transportation, storage, and disposal of radioactive wastes; and (3) the effectiveness of program management. These issues have affected the program *overall*; but the schedule and management issues raised in that report also have affected site-characterization efforts — especially the DOE's approach to underground exploration and testing at Yucca Mountain.

Underground exploration and testing will require extensive tunneling[1] through the mountain at various levels and across all geologic units to allow scientists to visually examine the complex geology at the site. It is especially important to determine the character and extent of the faults that cross the site[2] and to gain an understanding of the site's complex hydrogeology and geochemistry. Once the tunnels have been excavated, they will host an underground exploratory facility from which further testing will take place.

Excavating the underground exploratory facility, designated the exploratory studies facility, is an important milestone in the DOE's waste management program because it is key to achieving a number of other intermediate program goals. For example, if there are any "fatal flaws," or major disqualifying features that might lead to abandoning the site, they will most likely be revealed through the excavation of exploratory tunnels. In addition, once the exploratory facility has been excavated, scientists will be able to initiate important in-situ tests, such as thermal tests, which are necessary to evaluate how the natural geologic and engineered barriers actually will perform under conditions similar to those in a potential repository once waste has been emplaced. Data gathered during these tests will be used to determine site suitability, to predict long-term performance of the entire repository system, and to support application for the construction license — should the site prove suitable.

The exploratory facility also has the potential to become more than just a location for underground testing. If the site is judged suitable and is licensed for repository construction, major parts of the exploratory facility could be integrated into the repository. Therefore, the design of the exploratory facility should be compatible with any potential repository designs.[3]

---

1 *Tunneling* is referred to as an underground construction activity that results in a permanent facility. This contrasts with mining, which is the process of extracting mineral deposits from the earth.

2 The faults and fracture zones in the prospective repository horizon at Yucca Mountain tend to be near vertical, making their detection and characterization more feasible by tunneling.

The design and approach to excavating the exploratory facility have evolved substantially during the past four years, and much progress has been made. During the last several months, the DOE and its contractors have proposed a number of additional changes for further improvements. However, the Board is concerned that, because of past delays in initiating underground exploration and the overly optimistic schedules, important technical decisions about the design and excavation of the exploratory facility are being made without sufficient technical and scientific analysis of site-characterization issues.

This report reviews the status of the DOE's underground exploration and testing project at Yucca Mountain, Nevada; it suggests strategies to improve both the exploration and testing program and the approach to designing and excavating the exploratory facility. The Board makes several recommendations it believes will speed progress and improve cost-effectiveness. The Board believes the changes it is recommending can and should be made without slowing the momentum of important site-characterization activities currently under way at Yucca Mountain.

3 According to 10 CFR 60.15, "the number of exploratory boreholes and shafts shall be limited to the extent practical consistent with obtaining the information needed for site characterization" and "... exploratory boreholes and shafts in the [potential] geologic repository operations area shall be located where shafts are planned for underground facility construction and operation."

Exploration and Testing — Designing and Excavating the Exploratory Facility

According to a DOE presentation to the Board on April 22, 1993, the underground exploration and testing program has a number of key objectives including gathering otherwise unobtainable data on the major geologic features (units, faults, and contacts) throughout the mountain; gaining access to the underground so that various in-situ large-scale thermal, hydrologic, and mechanical tests can be initiated; and allowing a continuous, early look at the natural system to assess site suitability and provide critical data for repository design.

The Board concurs with these general objectives. And, in the following discussion offers suggestions for developing an improved strategy for underground *exploration* and *testing* at the Yucca Mountain site[4] that is carefully linked to the design and approach to excavating the underground exploratory facility.

Strategies for Exploration and Testing

The DOE's plans for exploration and testing have changed during the past four years, and much progress has been made. Recently, several changes have been proposed to further improve the program. Because the DOE's current plans and sequence for exploration and testing are still evolving, the Board would like to use this report to outline what it believes would be key elements in a comprehensive strategy for exploration and testing.

Explore across the geologic block

Since its first meetings in 1989, the Board has emphasized the importance of gaining early access to the underground at Yucca Mountain by excavating tunnels across major geologic features at the site. The geology of the site should be explored and tests conducted not only in the welded tuff [5] at the repository level but also in the nonwelded tuff above and below the repository level.

---

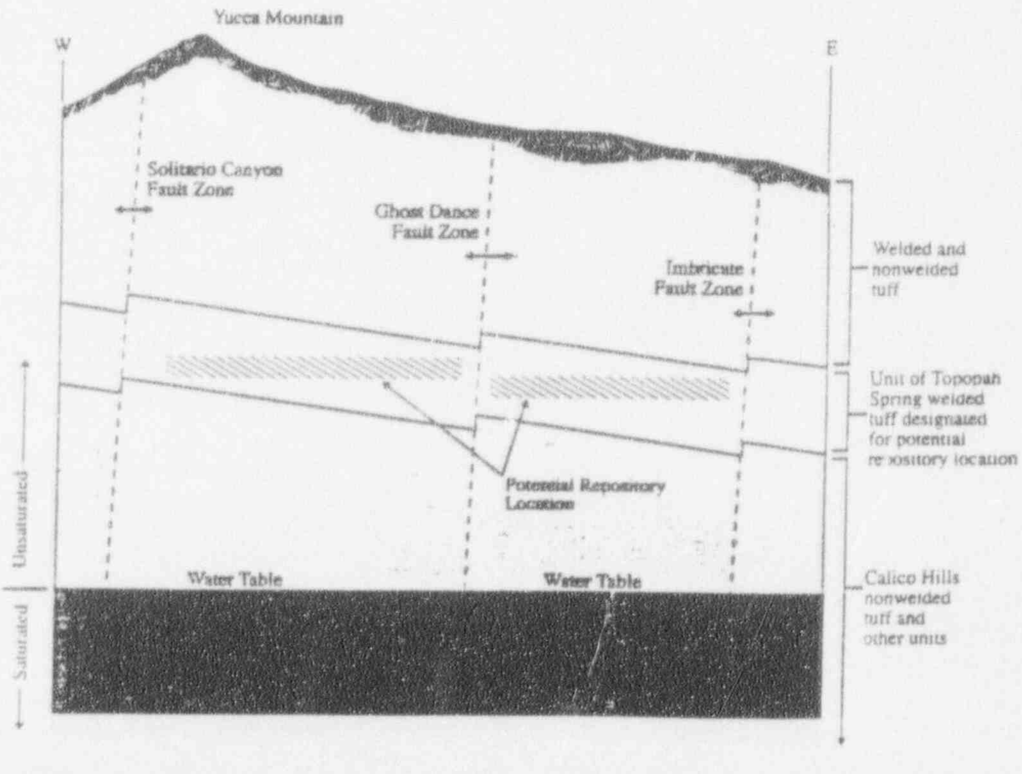
4 As used here, *exploration* of a site means excavating tunnels to allow human access for relatively short-term observations of geologic conditions. *Testing* means conducting longer-term scientific experiments in the excavated tunnels.

5 *Tuff* is a rock composed of compacted volcanic ash. It is either welded — consolidated by heat, pressure, and possibly the introduction of cementing minerals — or nonwelded. *Welded* tuff tends to be hard and highly fractured. Nonwelded tuff is usually porous and often relatively soft.

Many of the geologic features in the block, such as faults and fractures, are near vertical (see Figure 1). As a result, surface-based drilling and mapping will provide only limited information on these structures. Excavating access ramps (inclined tunnels) and horizontal tunnels (drifts) across these features is the only way to gain an accurate picture of their character and extent.

The exploratory facility design that resulted from the Exploratory Studies Facility Alternatives Study (SNL 1991) reflects this approach to exploration and testing. Tunneling *at* and *above* the repository level and *in the Calico Hills* unit below the repository will allow program personnel to visually examine and map fault zones, fractures, and joint sets in the mountain. Accordingly, any strategy for exploring and testing should include the following goals.

Figure 1 — Schematic rendering of major geologic units and vertical fault zones at the Yucca Mountain site *(not to scale)*



Note: Configuration of fault zones at depth is inferred.

Source: DOE. ... Characterization Plan. Vol. III, Part A, pp. 6–42. December 1988. (Modified from SNL 1987); Presentation to the NWTRB, July 13–14, 1993, SECTA-AD.CDR.124/7-2-93 (OCRWM 1993).

1. The DOE should first explore the major geologic features (above and at the repository level) by excavating the portal-to-portal loop (see Figure 2). Plans for the first phase of underground exploration call for excavating a ramp from the north portal down through the nonwelded tuff above the repository, and through the Imbricate Fault zone before reaching the repository level in the Topopah Spring welded tuff. The tunnel will then proceed across the Topopah Spring unit, crossing the Ghost Dance Fault at two places, in the central portion of the geologic block and again at the south end of the block, where the fault has a greater vertical offset. From there, excavation proceeds up the south ramp to the south portal. This first excavation sequence, which does not include excavation of any other tunnels, is referred to in this report as the *portal-to-portal loop*.

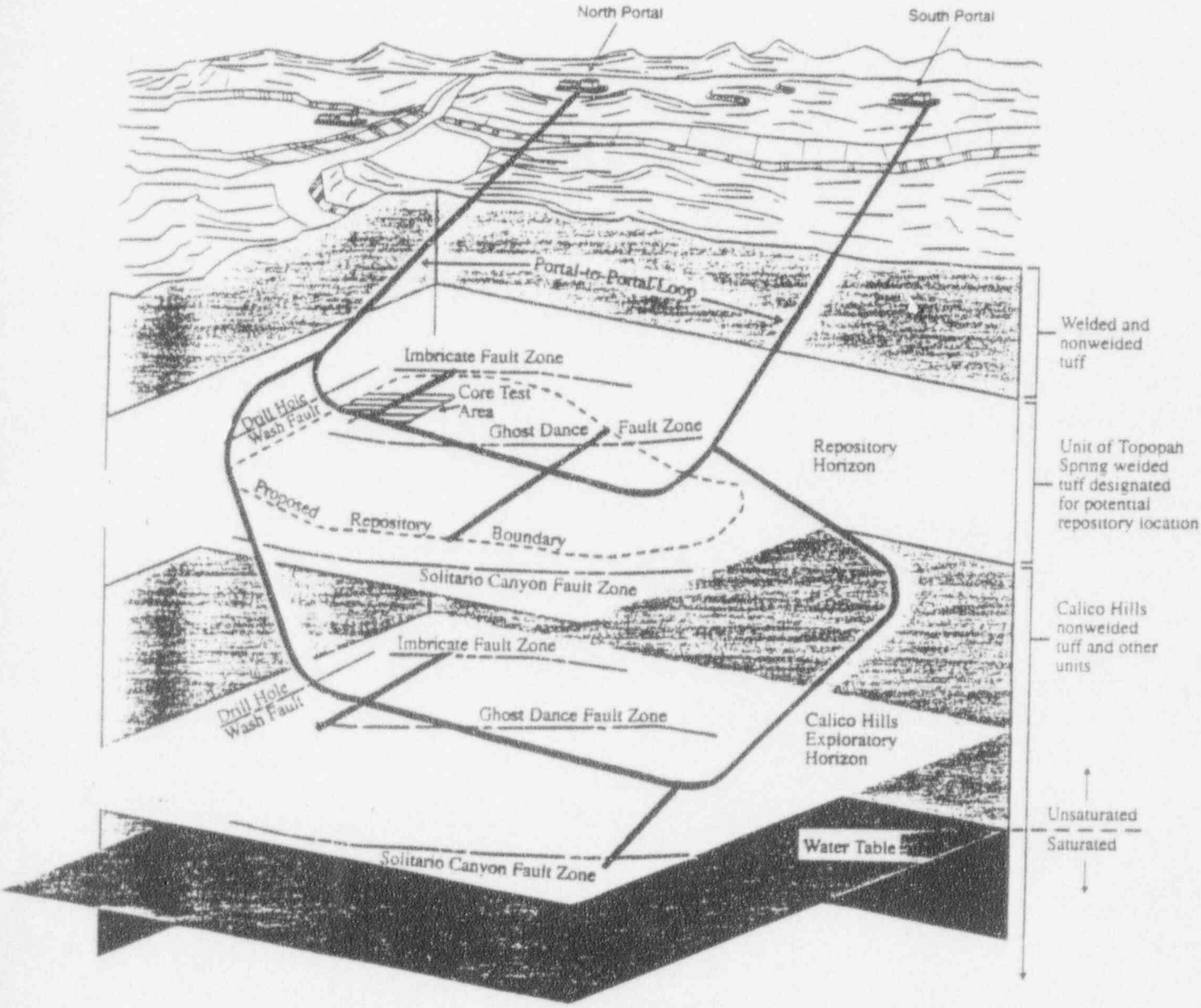
During excavation of the portal-to-portal loop, perched water and seepage may be observed and sampled. However, the only tests that should be undertaken during the excavation of the portal-to-portal loop would be to gather initial data on hydrologic properties across fault zones. To do this, near-horizontal boreholes will be drilled. They should be planned so that drilling can be conducted without interrupting the advance of the tunnel boring machine.[6] No other delays to machine operation should be allowed unless they are to gather critical, repository-relevant scientific data that would later be unrecoverable. After the portal-to-portal loop has been excavated, tunnels can be excavated east and west to penetrate the Imbricate Fault and Solitario Canyon Fault zones.

According to the DOE, limited core will be taken from the underground borings. Core will be drilled as soon as possible after the fault zone is excavated. The intent is to gain access to the borehole as soon as possible to reduce the effect of air exchange with the surrounding air mass. Sensitive temperature measurements made in the boreholes will be used to indicate water movement in the fault zone.

The ESF Alternatives Study (SNL 1991) calls for the tunnel boring machine to cross the Ghost Dance Fault zone at an oblique angle. Often, faults are not present as single surfaces but occur in zones comprising a series of individual fault planes as well as regions of fractured, crushed, and altered rock. Recent surface mapping has indicated, for example, that the Ghost Dance Fault zone at Yucca Mountain may be as wide as 1,000 ft. Intersecting it at a small angle during excavation of the portal-to-portal loop could mean tunneling through extensive lengths of the zone, which could cause serious support problems and slow machine advance.

6 One approach might be to mount the drill rig and support equipment on a platform that bridges the travel-way behind the tunnel boring machine so that supplies can continue to the machine while drilling is under way. This should be easy to do, especially if rail transport, with its smaller envelope, is used rather than rubber tired vehicles.

Figure 2 — Cutaway schematic rendering of Yucca Mountain geologic block showing currently proposed exploratory tunneling and possible location of repository *(not to scale)*



ote: Configuration of fault zones at depth is inferred.

urce: Presentation to the NWTRB, September 18–19, 1991. REFGBV5 P.125. NWTRB/9–18/19–91 (RSN 1991).

At the Board's July 1993 meeting, the DOE proposed several changes to the design of the exploratory facility; one calls for realigning the main tunnel so that it parallels the Ghost Dance Fault. Short, smaller diameter tunnels would later be excavated off the main tunnel to allow penetration and exploration of the Ghost Dance Fault at several points. This realignment could provide additional flexibility to the exploration and testing program and reduce the risks normally associated with excavating large tunnels through fault zones. However, since there may be secondary faults adjacent to the primary Ghost Dance Fault zone, flexibility in locating the main drift will be necessary so that it does not run along a secondary fault (it may not be possible to avoid more closely spaced fractures that parallel the faults).

2. The DOE should continue to thoroughly analyze the advantages and disadvantages of exploring in the Calico Hills. The Calico Hills consists of nonwelded tuff located below the repository level. Because the Calico Hills unit is a potential barrier to the transport of radionuclides from the repository down to the regional ground-water table, it is necessary to understand thoroughly the nature of jointing and faulting at this level.[7]

Based on the results of the Exploratory Studies Facility Alternatives Study and the Calico Hills Risk/Benefit Analysis (YMPO 1991), the DOE concluded in 1991 that early access to the Calico Hills would provide a net benefit when considering (1) possible postclosure risks, (2) the degree of scientific confidence in testing, (3) the potential for regulatory delay, (4) variations in program cost, and (5) the potential for phasing the tests. Examining the characteristics of the same fault zones *directly below* the repository level in the Calico Hills will provide valuable information on the flow of ground water through the unsaturated zone of Yucca Mountain.[8] As at the repository level, additional east-west drifts would be excavated off the main tunnel through the Calico Hills to allow a full east-west traverse of the major north-south trending features.

Recently, the DOE has mentioned budget constraints as a possible reason to forgo exploration across the block below the repository horizon in the Calico Hills. The Board strongly believes that any decision to forgo exploration of the Calico Hills using tunneling should be based on a thorough scientific and technical analysis of site-characterization issues.

---

7 Faulting and fracturing in the Calico Hills unit is likely to be much different from that in the welded tuffs of the Topopah Spring (i.e., the repository level) because the welded tuffs are harder and possibly highly fractured in the fault zones, whereas soft nonwelded tuffs are not as highly fractured and may offer reduced fracture permeability along faults.

8 To be able to evaluate the nature of faults at different levels it would be desirable to excavate portions of the tunnel in the Calico Hills unit directly below the portal-to-portal loop.

Initiate testing

The DOE's exploratory facility design currently calls for the excavation of extensive testing areas so that multiple, simultaneous testing can be conducted. Testing facilities include: 23 test alcoves in the north ramp, 21 test alcoves in the south ramp, 44 test alcoves in the Calico Hills ramps and loop, an "alternative shaft" that extends from the repository level to the surface, and a core test area consisting of 8,400 feet of tunnel containing numerous alcoves and support facilities.[9]

A recent DOE test planning package (YMPO, September 1992) defines 42 testing activities, which will be conducted within the exploratory facility. The 42 testing activities can be grouped into four categories: exploration (16 tests); thermal (5 tests); hydrogeology/geochemistry (12 tests); and, geomechanical/engineering (9 tests). Although the Board believes the plan is a good one, it feels that the facility design and test support are more complex than required for a well-prioritized and sequential testing program. Many of these testing activities could be combined or carried out sequentially. This might allow a simplification of the core test area and, perhaps, of the exploratory facility (see discussion beginning page 17). In the following discussion, some approaches are suggested that could make the testing program more efficient.

1. Exploration — test during excavation. A number of testing activities could be conducted while excavating the tunnels and drifts. These include mapping the geology; collecting samples of perched water if encountered; collecting rock samples; evaluating excavation methods; monitoring ground support systems; monitoring drift stability; and determining the hydrologic properties of major faults. As noted previously, however, testing during excavation of the portal-to-portal loop should be limited to avoid interrupting the advance of the tunnel boring machine.

2. Thermal testing — reinitiate underground testing as soon as possible. A significant issue currently facing the Yucca Mountain project is determining the most appropriate thermal loading for a repository.[10] Since 1991, a strong rationale has evolved for the argument that thermal effects will be the main cause of vapor and water flow in a repository, no matter what thermal loading ultimately is chosen. The rationale is based on models that are backed by limited data obtained from G-Tunnel thermal testing. The G-Tunnel thermal tests were conducted over

9 Based on the 1992 construction cost estimate for the exploratory facility (RSN 1992).

10 *Thermal loading* refers to the amount of high-level waste emplaced per acre of repository area. Higher loadings cause higher repository temperatures, which may help drive moisture away from waste packages but which may also make projections of long-term repository performance more difficult.

a nine-month period in welded tuff at Rainier Mesa, Nevada Test Site. Tests consisted of a single heater simulating *horizontal* borehole emplacement of a small waste package (an alternative to the vertical borehole concept then favored). Because no additional testing has been conducted since the G-Tunnel effort was terminated in 1989, these data, which are very limited in scope, provide the only underground thermal test data available to the program.

Because of this four-year hiatus in underground thermal testing, the program currently lacks sufficient field testing experience, proven instrumentation for underground testing, and a well-developed testing strategy. The present DOE plans call for thermal testing to be conducted in the core test area off the main tunnel of the portal-to-portal loop. Unfortunately, a recent DOE schedule shows the reinitiation of thermal testing in the core test area has continued to slip during the last 16 months, from November 1996 to early 1998 (DOE 1993). Underground thermal testing should be reinitiated as soon as possible. The Board believes that it is critical to develop instrumentation and procedures and gain as much testing experience as possible *prior* to initiating testing in the core test area. The Board places high priority on understanding the effects of thermal loading on a potential repository through a *continuing* program of thermal testing.[11]

An overall testing strategy presented to the Board by the DOE in July as an "ideal" approach calls for at least three years of prototype underground thermal testing (outside of the repository block). This would be followed by testing in the core test area consisting of two or more years of test planning, ten years of testing, and one-and-a-half years of analysis and data reduction.[12] All underground test configurations would be designed to simulate the anticipated repository configuration.[13]

Several proposals for reinitiating prototype underground thermal testing have been presented to the Board. At a Board meeting on the exploratory facility in November 1992, the DOE reviewed the advantages of developing an in-situ prototype thermal test facility at Busted Butte (several miles south-east of Yucca Mountain in an outcropping of Topopah Spring welded tuff). At the July 1993 Board meeting in Denver, the DOE made a strong case for initiating a large heated-block test, which was referred to as an "off-block prototype in-situ thermal

---

11 In-situ heater tests of sufficient size to include scaling and heterogeneity effects are needed to test fundamental hypotheses. It was proposed that in-situ testing be defined to meet two needs, short to medium duration (i.e., 1 to 7 years) to support and defend license application, and long duration (i.e., 50 to 200 years) to provide performance confirmation (Wilder 1993).

12 Ibid.

13 Ibid. One configuration would make use of 21-5.5 Kw heaters in three parallel drifts, simulating repository waste emplacement drifts.

test."[14] This plan involves cutting a 10-ft by 10-ft by 15-ft block out of welded tuff, installing heaters and instrumentation, and initiating testing that would continue for five to seven years. One disadvantage of this option is the data obtained would be of limited value because a large block is a poor representation of a potential repository.[15]

Given the potential for continuing delays in the construction of the exploratory facility — and access to the core test area — development of a prototype underground testing facility (outside the core test area) may prove to be a very timely and cost-effective investment, and could reduce the urgency of early excavation of the core test area.

3. Hydrogeologic/geochemistry testing — begin as soon as possible. Seven of the twelve planned hydrology/geochemistry tests are part of the unsaturated-zone percolation test plan. In its test prioritization studies, the DOE has referred to these tests as having high priority (YMPO, November 1992). The DOE plans to conduct these tests in alcoves throughout the exploratory facility to evaluate fluid and gas flow in geologic units, between units, and across major and minor structures (faults, joints, bedding plane partings). These tests should be started as soon as possible but should not interfere with the advance of the tunnel boring machine during the excavation of the portal-to-portal loop. Here again, perhaps tests could be carried out from drill platforms that bridge the travel-way behind the tunnel boring machine so as not to delay excavation.

4. Geomechanical/engineering testing — perform during excavation. Much of the needed data on ambient rock characteristics and geomechanical properties can be gathered through well-planned mapping and construction monitoring activities conducted *during* excavation. The movements and mechanical stability of openings can be monitored during excavation using multiposition extensometers. How thermal loadings will affect the mechanical properties of the rock can be determined as an add-on to the thermal testing needed to evaluate the hydrologic properties of the host rock.

---

14 Ibid.

15 The Board also is aware of a proposal to set up a testing facility at Fran Ridge. This proposal had been studied prior to the Board's inception in 1989. The Board has not been briefed on the status of this proposal.

Establish exploration and testing strategies, priorities, and goals

The DOE should develop a *comprehensive strategy* for exploration and testing. The current revised plans for conducting sequential exploration and testing, although much improved, are still evolving. The plans appear to reflect some degree of general prioritization; however, no detailed documentation has been made available to the Board that identifies either specific priorities or a basis for any prioritization. This lack of a comprehensive testing strategy is reflected in the current complex design of the underground facility, which contains excessive test support facilities and utilities. Specific milestones for excavation *and* testing should be established. The sequence for exploration and testing in the exploratory facility should be organized around specific intermediate goals and should be consistent with scientific needs, realistic funding expectations, and the efficient management of the excavation of the underground exploratory facility.

Continuous reevaluation of the exploration and testing program as the final design of the exploratory facility progresses will provide the opportunity to fine tune the program. For example, the DOE should consider relocating some tests presently planned for the surface-based drilling program to drill sites within the exploratory facility. Tunneling provides the opportunity to locate the near-vertical faults, which have a strong and local effect on the hydrology and geochemical properties of the rock. When a fault is crossed, sampling can be undertaken across the fault and at known distances from it. The resulting data can be better related to the existing features. In some cases, this could offer an advantage over drilling long drillholes from the surface. In addition, given the slow drilling rate of the LM-300 deep dry coring drill and the long drill lengths required when drilling from the surface, shifting appropriate tests to the underground could speed program progress and reduce costs.[16]

Conclusions

1. Exploring across the geologic block to gather the data necessary for an early determination of the site's suitability for repository development is of highest priority. Exploration should be conducted across the site above, at, and below the repository level. Tunnels should intersect anticipated major faults and any major unknown structures passing through the repository block so that typical in-situ conditions in the key geologic units (including frequency of fractures) can be evaluated.

16 The DOE's surface-based drilling program foresees drilling approximately 40 holes to depths of 1,500 to 3,000 ft. The first hole, UZ-16, which is 1,686 ft deep, took ten months to drill.

2. Underground thermal testing should be reinitiated as soon as possible. The DOE needs to understand the effects of heat on a potential repository through the establishment of a *continuous* testing program. Because of the four-year hiatus in underground thermal testing and the possibility for continuing delays in the excavation of the exploratory facility, the development of an off-site underground test facility has merit. Such a facility also could reduce the urgency of early excavation of the core test area.

3. Some drilling and testing presently planned for the surface-based program could be accomplished better (or more economically) from drill sites within the exploratory facility.

4. The program lacks a *comprehensive strategy* for exploration and testing that is based on established intermediate goals and is consistent with the scientific needs of site characterization, realistic funding expectations, and the efficient management of the excavation of the underground facility. Although greatly improved, the current exploration and testing program should contain specific milestones and priorities for exploration and testing in the exploratory facility.

Strategies for Design and Excavation of the Exploratory Facility

The design of the underground facility and the DOE's excavation approach have evolved substantially during the past four years. At the Board's July 1993 meeting, the DOE presented the most recent proposed changes to its current exploratory facility design. The Board believes that several of the proposed design changes (e.g., reducing tunnel gradients) offer improvements over the previous design. Some of the changes being considered require further evaluation (e.g., realigning the portal-to-portal loop; for example, at what distance should the portal-to-portal loop parallel the Ghost Dance Fault?).

The Board would like to take this opportunity to briefly review strategies it believes will further improve the DOE's current exploratory facility design and speed the underground excavation and testing program. Although the following discussion addresses the original baseline plan, recently proposed changes to the current design also are addressed where appropriate. The Board suggests that the DOE consider the following options during excavation of the underground exploratory facility.

Delay competing excavation activities until completion of the portal-to-portal loop

The fastest, most economical excavation of the 26,000-ft-long portal-to-portal loop from the north portal through the main tunnel to the south portal would be to proceed without competing simultaneous excavation activities from the same portal. Multiple excavation activities from a single portal will interfere with the advance rate of the tunnel boring machine. Interruptions to machine operation should only be allowed if the need arises to gather critical, repository-relevant scientific data that would later be unrecoverable. After the machine has transited from the north to south portals (an operation that should take about 12 months), access would be available from the south portal for excavating alcoves and turnouts and to begin early testing activities. At the same time, activities supporting excavation of the exploratory facility, such as mucking,[17] could be continued from the north portal. The Board strongly supports the DOE's recent proposal to drive the portal-to-portal loop without interrupting the advance of the tunnel boring machine.

After completing the portal-to-portal loop, excavation of additional east-west tunnels, as well as the core test area, can begin using a smaller tunnel boring machine. Driving a tunnel west to the Solitario Canyon Fault zone is high priority because it would complete a full east-west traverse of the major north-south trending features. Also high priority is excavation through the Calico Hills unit directly below the proposed repository horizon. To be able to evaluate the nature of faults at different levels it would be desirable to excavate portions of the tunnel in the Calico Hills unit directly below the portal-to-portal loop. Access to the Calico Hills could be obtained from the north-south ramps (see Figure 2) or from a separate surface portal. Creating a separate portal offers the advantage of reducing the number of activities taking place off the portal-to-portal loop and reducing the possibility of adversely affecting the repository operational area. A separate portal also might allow excavation of the Calico Hills unit to be carried out as early as funding will allow.

Use rail to support tunnel boring machine operation

The Board recommends the use of rail, rather than rubber tired vehicles, to support tunnel boring machine operations. The use of rail to transport people and materials in and out of the tunnel is more efficient and cost-effective. Rail will

17 The removal of all excavated rock (muck) will be undertaken using a conveyer, which will transport the excavated rock out through the north portal. Conveyer operations should be devoted entirely to the support of the tunnel boring machine until completion of the portal-to-portal loop.

greatly reduce the potential for introducing petroleum products into the underground. Rail lines can be laid quickly on excavated tunnel floors without further floor preparation, and rail will allow a wider ventilation area and make it easier to back up the tunnel boring machine during excavation of alcoves. Finally, rail transport offers the safest means of controlling the movement of people into and within an underground facility. In addition, the use of rail generally requires a smaller operational area (7-by-7-ft rather the 12-by-12-ft required by rubber tired vehicles [Sperry 1993]), which will allow a more efficient use of the tunnel space. This space could be used, for example, to install platforms that bridge the rail from which testing and drilling operations could be carried out during excavation of the portal-to-portal loop without interrupting the advance of the tunnel boring machine. This could allow early initiation of important hydrogeologic testing activities while reducing the number of alcoves that will be needed.

The use of conventional rail support for tunnel boring machine operation requires relatively flat gradients along the lengths of the tunnel.[18] During the July 1993 Board meeting, the DOE presented proposals to reduce the relatively steep gradients in the baseline plan. The Board supports the DOE's decision to lower the gradients along the ramps and main tunnel to 2.6 percent or less, which allows the use of conventional rail transport during exploratory facility construction.

Keeping the gradients along the tunnels relatively flat offers an additional advantage. During recent months, interest has increased in emplacing large, self-shielding waste packages in repository tunnels (in-drift emplacement). An exploratory facility with steep gradients could *foreclose* the use of conventional rail in a repository. If in-drift emplacement proves to be the preferred strategy, repository gradients should be flat, and the option of rail transport to haul the large waste packages should be maintained.

Excavate smaller diameter tunnels outside the portal-to-portal loop

The portal-to-portal loop, which will be advanced without competing excavation activities, will be excavated with a 25-ft-diameter tunnel boring machine. The DOE plans to excavate *all other tunnels* (including those excavated off the portal-to-portal loop) using smaller tunnel boring machines.[19] There are sound

18 The baseline plan (DOE 1988), as revised in 1991 as a result of the ESF Alternatives Study (SNL 1991), shows steep gradients for the main north-to-south loop: a slope of 6.9 percent from the north ramp to the Topopah Spring level, then a slope of 4.7 percent across the block, and a 1.6 percent climb to the south portal. These gradients are too steep for the use of conventional rail.

19 This includes the tunnels in the underlying Calico Hills formation, in the east-west exploratory tunnels, in the core test area, and in any prototype testing facility.

technical, cost, and schedule reasons why excavating smaller tunnels outside the portal-to-portal loop is preferable. Smaller diameter tunnels are more stable structurally, particularly when excavating in fault zones. Using a smaller machine outside the portal-to-portal loop will be more efficient and more cost-effective because smaller diameter tunnel boring machines advance faster through rock,[20] can be moved more rapidly from point to point, and can be used more efficiently to excavate intersections. Finally, the smaller the tunnels, the easier they are to backfill if they cannot be integrated into a potential repository.

The Board supports the DOE's decision to use a smaller machine outside the portal-to-portal loop. However, the DOE must plan now for the start of additional tunnels with at least one, perhaps two, smaller tunnel boring machines. According to the DOE schedule (DOE 1993), the new 25-ft machine should begin excavation of the portal-to-portal loop in July 1994. Based on industry standards and the DOE decision to excavate portal to portal without interruption, excavation of the portal-to-portal loop should take no more than approximately 12 months. If this schedule is met, the contractor should have the smaller tunnel boring machine on site ready to begin excavation by July 1995.

The Board is concerned that possible delays in acquiring a smaller machine could further delay the site-characterization program. Because of these potential delays and because of budget constraints in the program, the Board suggests that the DOE let the contractor acquire all future machines (equipment should be owned by the contractor). A number of options are available for obtaining a machine at much lower costs in much less time than was required for the DOE to purchase the new 25-ft machine.[21] For example, the contractor could rent, or possibly purchase, a used machine for use on the project.

---

20 Industry experience during the last few years indicates that minimum overall advance rates during tunneling should run about 100 ft per working day for a 25-ft machine and 125 ft per working day for an 18-ft machine in the welded tuff of the Topopah Spring formation. Rates in the softer nonwelded tuff of the Calico Hills formation for a 16- to 18-ft machine should average 175 ft per day. Construction risks and delays increase with increased tunnel size and include delays to install additional rock support in fault zones or other zones of low rock quality; for increased machine maintenance due to larger, less reliable components; for more frequent cutter changes (especially in hard rock); and slower production rates. Costs also increase with increasing size. Experience shows that a 25-foot tunnel costs about 1.5 times as much as an 18-foot tunnel. (See also Gertsch and Ozdemir 1991.)

21 In a recent memorandum (NWTRB, August 1993), the Board recommended to DOE management that consideration be given to acquiring a government-owned tunnel boring machine currently parked in N-Tunnel at Rainier Mesa, Nevada, for use at nearby Yucca Mountain.

Use a tunnel boring machine to excavate the core test area

The core test area will be the location of critical intermediate and long-term thermal testing. To maximize the ability to extrapolate test results to repository scale, this testing should be carried out under conditions that approximate *as exactly as possible* the conditions in a potential repository, which will be excavated using a tunnel boring machine.[22] Under the present design, the core test area is very complex (see Figure 3). It contains many rooms and alcoves, a number of which have been designated for use as offices, store rooms, shops, and warehouses. Its current configuration contains many right-angle intersections making excavation with a tunnel boring machine impossible. The Board recommends that the core test area be simplified to allow excavation using a full-face tunnel boring machine that is capable of a small turning radius. Alcoves planned for activities other than thermal testing should be minimized. Use of drill and blast technology or other equipment, such as a mobile miner or other high-risk technologies, should be avoided.[23]

Reduce and simplify surface and subsurface facilities and utilities

Plans for surface and subsurface facilities and utilities have not been modified sufficiently to reflect the revised excavation plan; they still reflect to a large degree the extensive support necessary for *multiple* operations from the same portal and *simultaneous* testing.[24] At the recent north ramp 90 percent design review, the Board learned that the muck conveyor system is still being designed to support multiple excavation operations from the same portal as well as drill and blast operations during the excavation of the portal-to-portal loop. Now that the DOE has decided to delay competing excavation activities until after completing the portal-to-portal loop and to use smaller tunnel boring machines for all other

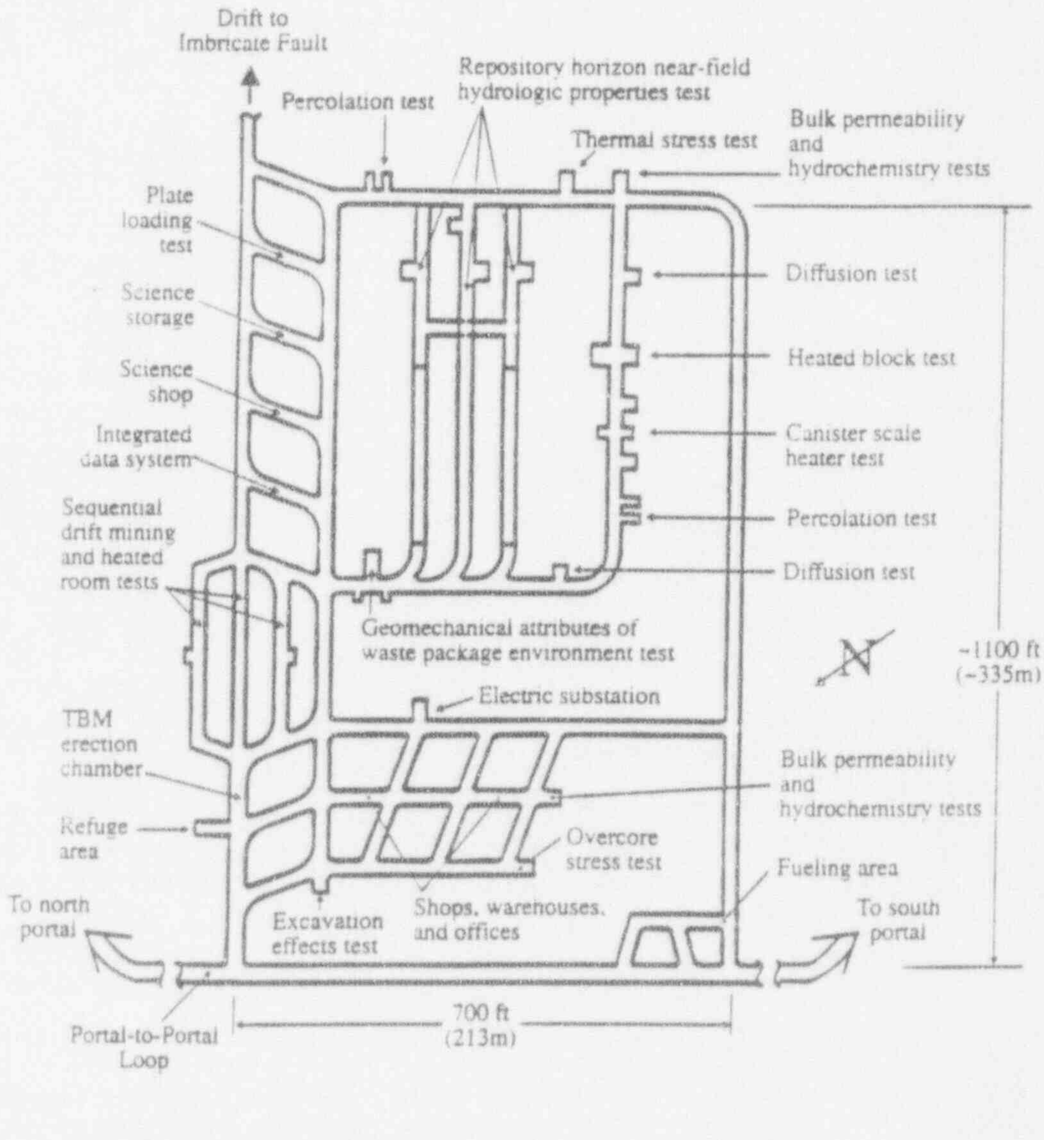
---

22 A recent LLNL prepublication report (Buscheck, Wilder, Nitao, 1993) argues that heater tests are required within the proposed repository block at thermal loading conditions that are representative of proposed repository conditions.

23 Two significant concerns are the roughness of tunnel walls and the extent of fracturing of rock surrounding the tunnels that would be created using drill and blast methods. Roughness may affect radiative heat transfer from waste packages to tunnel walls. Mechanical stability and stress conditions in the wall rock would also be significantly altered by drilling and blasting.

24 For example, support facilities at the Topopah Springs level consist of a power substation, waste water facility, and 18,700 ft of utilities including dual 15kv power feeds, mechanical utilities (a 6" compressed air line, an 8" water line, and a 6" drain line), and an integrated data system (fiber optics). The core test area contains a power substation, and 10,500 feet of utilities. The Calico Hills contains a waste water facility, shop facility, two power substations, and 13,300 feet of utilities (RSN 1992).

Figure 3 — Currently proposed core test area *(plan view)*



Source: DOE. YMSCP. Title 1. *Design Summary Report*. Vol. 3. Design Drawings. September 3. 1991. Drawing No. YMP-025-2-MING-M133 (DOE 1991).

excavation, the underground utility requirements are no longer needed. They should be reduced to reflect the revised sequential exploration and testing program.

Portal development and surface facilities also should be simplified to reflect the requirements of the revised program. The Board strongly supports the DOE's recent decision to eliminate the steel arch portal extension in the north portal and suggests other simplifications, such as the use of temporary surface support facilities, to save money and speed program progress.

Develop possible repository designs in conjunction with the evolving exploratory facility design

As mentioned above, if the site at Yucca Mountain proves suitable and is licensed by the Nuclear Regulatory Commission for repository construction, the exploratory facility would probably become an integral part of the repository. Although extensive tunneling will be required, the exploratory facility should be no larger than necessary for exploration and testing. At the same time, potential repository preliminary designs must be developed *in conjunction* with the final design of the exploratory facility.

Possible options for a repository design were presented to the Board by the DOE in 1990 and again recently. One design included a multilevel repository with flat gradient (near horizontal) tunnels at each level. This design would allow the use of conventional rail during the construction of the proposed repository as well as during repository operation. As already mentioned, this option is becoming more attractive as interest grows in the use of large, self-shielding, drift-emplaced waste packages. The current change in the exploratory facility from steep to flat gradients is compatible with a multilevel repository design.

Conclusions

1. The DOE's current plan to advance the tunnel boring machine through the portal-to-portal loop at the repository level from the north to the south portal without interruption from competing excavation or testing operations is strongly supported by the Board. This is not only the most efficient and cost-effective construction approach, but it also will allow earliest access to major geologic features and provide access to the exploratory facility from both the north and south portals. Assuming only minimal delays, this transit can be accomplished in approximately 12 months.

2. The use of rail, rather than rubber tired vehicles, is the most efficient and cost-effective way to support tunnel boring machine operations. Rail will allow more efficient use of tunnel space.

3. Plans are not yet under way to acquire additional smaller diameter tunnel boring machines for excavating tunnels off the portal-to-portal loop and in the core test area. Possible delays in acquiring smaller machines could further delay the site-characterization program.

4. The surface and subsurface facilities and utilities still have not been sufficiently reduced to reflect recent project changes. Once that has been accomplished, the site-characterization program can proceed more quickly and at reduced costs.

5. Conditions in the core test area, the site of critical intermediate- and long-term thermal testing, should approximate as precisely as possible conditions that will be present in a potential repository. Excavating the core test area using a full-face tunnel boring machine, rather than using drill-and-blast techniques or other high-risk excavation technologies, will create the necessary conditions.

Recommendations

The Board makes the following recommendations.

Recommendations for exploration and testing

1. Explore across the block to access the major geologic features, many of which are near vertical and north-south trending. These features should be explored above, at, and below the repository level. Any changes to this plan should result from sound analysis of site-characterization issues.

2. The DOE should reinitiate its underground thermal testing program as soon as possible to allow the development of instrumentation and procedures and to gain as much testing experience as possible *prior* to initiating testing in the core test area. Given the potential for continuing program delays — including delays in excavating the core test area — development of an underground testing facility (outside the core test area) may prove very timely and cost-effective.

3. Existing plans should be expanded to produce a *comprehensive strategy* for exploration and testing. Priorities and goals should be based on specific intermediate goals and be consistent with the scientific needs of site characterization and with realistic funding expectations. The strategy should reflect an integration of exploration and testing priorities with efficient excavation of the underground facility based more on current practices in the underground construction industry.

Recommendations for design and excavation

1. The DOE's plan to excavate all tunnels other than the portal-to-portal loop using smaller tunnel boring machines is a good one. However, considering the schedule for the portal-to-portal loop, plans must be made *now* to acquire at least one smaller tunnel boring machine so that excavation of other tunnels can begin as soon as the portal-to-portal loop has been completed. The construction contractor, rather than the DOE, should write the specifications for and purchase its own machines based on the needs of the project.

2. Surface and subsurface facilities and utilities should continue to be simplified to reflect the new excavation sequence; as part of this effort, the core test area also should be simplified so that it can be excavated using a full-face tunnel boring machine.

Management at the Project Level

The Board recognizes the complex regulatory and oversight constraints facing the U.S. high-level waste management program in general and the challenges inherent in managing this large scientific and engineering project in particular. However, most of the construction activities required to develop the exploratory facility are well within the experience of the underground construction industry.[25] Tunnel support and excavation conditions are not particularly extreme as compared to other underground projects, and technology for rapid and safe excavation and tunnel support are well developed. The Board believes a wealth of expertise and experience exists from which the DOE could draw — even for this first-of-a-kind facility.

Project Decisions

The Board has found that important project decisions often do not reflect what would be considered standard practice in the underground construction industry. Three areas where improvements would make the project more efficient are discussed briefly below.

1. Contracting practices for the project are not typical of the industry and do not encourage competition or innovation. According to the DOE, a cost-plus award-fee contract was chosen for the exploratory facility because construction goals are subject to being overridden by scientific and technical needs. However, the Board remains unconvinced that a cost-plus award-fee contract is the best type of contract to be used for the design and construction of the exploratory facility.[26] The standard industry contract is the firm fixed-price contract, which is open to competition and awarded to the lowest bidder. It is the most common type of contract used because it provides the greatest performance incentives to the contractor.

To help control the cost and time required for exploratory facility construction, the DOE should develop cost and schedule incentives for current contracts. The Board also suggests that the DOE consider using conventional fixed-price or cost-plus incentive-fee contracts on future portions of the exploratory facility.[27]

---

25 *Underground construction industry* refers to those who participate in the construction of permanent underground facilities (e.g. hydroelectric, public transportation, public water systems).

26 Questions also have been raised by DOE Assistant Secretary Thomas P. Grumbly about the efficiency of the DOE's award fee contracts (*Energy Daily*, Monday, July 19, 1993).

27 This type of contract could be used, for example, for the excavation of accesses and the traverse of the Calico Hills, especially if exploration is conducted from a separate portal or during the construction of a prototype thermal test facility.

The Board also believes that, to avoid the potential litigation associated with contractual relationships, a disputes review board should be included in all construction contracts. These boards have been used successfully for 20 years in the construction industry to reduce the adversarial relationships between owner and contractor that often result from differing contract interpretations. Standard contract language exists for establishing a disputes review board.[28]

2. The DOE departed from the standard practice in the underground construction industry when it developed specifications for and purchased a new 25-ft tunnel boring machine. There is little precedent in the industry for the owner of a project purchasing the tunnel boring machine that will be used by a contractor on a cost-plus basis. The typical approach is to obtain the services of a contractor who then writes the specifications for and purchases (equipment is owned by the contractor) all of the equipment necessary to do the job, including the tunnel boring machine, its trailing gear, and any other elements necessary to support excavation.[29] When the job is over, the contractor has the option of selling the machine and equipment or using it on another job.

3. In general, the Board believes that the excavation of the exploratory facility could be accomplished more quickly and at less cost if the tunnels and support facilities were designed only to meet the needs of exploration and testing. Instead, the DOE appears to have overdesigned the exploratory facility. For example, the number of alcoves in the facility in general and in the core test area specifically are excessive (see discussion, page 17). The portal-to-portal loop is being excavated with larger diameter tunnels than necessary for an exploratory facility,[30] and it appears that many special, and probably unnecessary, features are included in the DOE's specifications for the new 25-ft tunnel boring machine. Finally, utilities and support facilities are in excess of what is required for this exploration program. Reducing the complexity of the facility and of the surface and subsurface facilities and utilities will speed program progress and reduce costs.

The U.S. underground engineering and construction industry is a world leader in designing, managing, and constructing major underground projects. If the DOE were to adopt applicable technology and aspects of the design, management, and

---

28 See National Research Council, 1974 and American Society of Civil Engineers, 1991.

29 The contractor is completely accountable for the performance and daily operation of the machine. As a result, the contractor will be motivated to design, acquire, operate, and maintain all equipment (including tunnel boring machines) in a timely and cost-effective manner.

30 In a March 1993 letter to the Secretary of Energy (NWTRB, March 25, 1993), the Board expressed its view that "the technical basis for the DOE's choice of larger diameter tunnels for assessing site suitability was not a compelling one."

engineering practices used in the industry, time and cost savings could be realized that could help minimize potential delays and free money for important scientific and technical activities.

To take advantage of this existing experience, the DOE should establish as soon as possible a geoengineering board, which would work with the technical and management staff and report to Yucca Mountain project management. Large underground construction projects, such as subway systems, the superconducting super collider, and hydroelectric facilities, use such geoengineering boards. These boards are typically composed of four-to-seven members with expertise in engineering, construction, and management of large underground projects. Such a geoengineering board could meet regularly with Yucca Mountain Project management, staff, and contractors to review detailed decisions early on — *when they are first being made*. Potential members should be nationally recognized and be selected based on experience serving on similar boards for projects of commensurate complexity.[31]

The DOE does at times use technical review panels. However, these technical reviewers traditionally are employed by the DOE or firms that are under contract to the DOE, and they often lack adequate experience on tunneling projects of similar complexity. For example, at the recent 90 percent design review, of 41 review team members, all were employees of the DOE or under contract to the DOE on this program,[32] and few had experience on projects using tunnel boring machines. As a result, issues such as those mentioned above, which could easily have been resolved early in the design stage by a geoengineering board, were still being evaluated during the 90 percent design review.

Organizational Structure and Management at the Project Level

As the Board stated in its *Special Report*, the overall civilian radioactive waste management program (OCRWM) is large and diffuse, and specific responsibilities are unclear. This also is true at the Yucca Mountain project level where numerous contractor groups have been hired to perform engineering and construction tasks. As of November 30, 1992, employees from 24 organizations were working on the project.[33] Multiple levels of management are involved in decision making, and responsibilities are unclear.

31 Because of the breadth of its mission and reporting mandate, the NWTRB is not equipped to carry out the detailed review that would be asked of such a geoengineering board.

32 Presentation at the DOE's 90 Percent Design Review, July 19, 1993 (TRW 1993).

33 More than 1236.7 full-time equivalent contract employees (DOE 1992).

The OCRWM hoped to be able to place a repository in operation by 2010 through very large increases in annual funding. However, these increases have not been requested by the DOE, nor appropriated by Congress. When increased funding seemed likely, or at least plausible, maintaining a large project overhead and infrastructure may have appeared reasonable. However, concern has been expressed during the past year by a number of organizations, including Congress,[34] about the high proportion of funding going to program overhead and infrastructure. The Board is concerned that relatively small amounts of funding remain for important scientific and technical activities.

The problem of funding allocation has had an ongoing effect on the program's technical activities. For example, citing lack of funding, the DOE terminated thermal testing in G-Tunnel in 1989 and delayed initiation of underground exploration and testing in 1992. These delays, together with the DOE's attempt to meet overly optimistic program deadlines, resulted in an excavation approach that called for multiple excavation activities from a single portal and a *compressed* schedule for conducting important tests, including tests related to thermal loading. Although the DOE recently has proposed (and the Board supports) changing its excavation approach, funding choices will likely continue to affect site-characterization efforts. For example, recently the DOE cited potential lack of funding, rather than sound technical analysis, as a possible reason to forgo excavation of the Calico Hills unit. And funding choices may affect when important underground thermal testing will be reinitiated, or when the contractor will begin acquisition of another tunnel boring machine.

The Secretary of Energy has recently committed to undertaking a review of the financial aspects of the civilian radioactive waste management program. The Board recommends that such a review include an evaluation of the effects that funding allocation decisions could have on progress in the site-characterization program. To improve financial accountability and free additional money for site work and testing, the Board believes that the DOE should develop a more efficient system for managing the exploratory facility design and construction. Emphasis should be place on improving accountability and on establishing incentives for cost-effective and timely performance of the contractors. A more efficient management structure should allow the DOE to allocate a portion of funding currently going to the project's overhead and infrastructure to the exploration and testing program. Funding allocation decisions should be made in such a way as to ensure that the momentum of the exploration and testing program currently under way at Yucca Mountain is maintained.

34 U.S. Congress, House 1992; U.S. Congress, Senate, 1993; GAO 1993.

Conclusions

1. As many have noted, a high percentage of funds have been allocated to maintain a large overhead and infrastructure. This has left relatively limited amounts for site-exploration and testing activities. The DOE cited insufficient funds as the reason for terminating underground thermal testing in 1989 and for the delay of the design and construction activities for the exploratory facility in 1992. Although underground work has begun, if the DOE does not allocate more funding to the exploration and testing program, the delays will likely continue.

2. Contracting and purchasing practices established by the DOE do not contain incentives for cost-effective and timely performance of contractors.

3. Project management is diffuse, and the decision-making process involves many different contractor organizations, multiple levels of management, and unclear accountability.

Recommendations

1. Consistent with practices in the underground construction industry, the DOE should establish a geoengineering board with four-to-seven members who have expertise in the engineering, construction, and management of large underground projects. Members should be nationally recognized and be selected based on their previous experience serving on similar boards. Such a geoengineering board would meet regularly with Yucca Mountain project management, staff, and contractors to review detailed decisions early on — as they are being made and to provide guidance on improving the management of the design and excavation of the exploratory facility.

2. The DOE should develop a more efficient system for managing the exploratory facility design and construction that contains greater accountability and incentives for cost-effective and timely performance of the contractors.

3. The Secretary of Energy's review of the financial aspects of the civilian radioactive waste management program should include an evaluation of the program's funding allocation decisions. This review should help find ways to maximize the funds that are being made available for scientific studies and to ensure that the momentum of the exploration and testing program under way at Yucca Mountain is maintained.

References

American Society of Civil Engineers - Technical Committee on Contracting Practices of the Underground Technology Research Council. 1991. *Avoiding and Resolving Disputes During Construction: Successful Practices and Guidelines*. 1991. New York.

Buscheck, T., D. Wilder and J. Nitao. 1993. Pre-publication report. *Large-Scale In Situ Heater Tests for Hydrothermal Characterization at Yucca Mountain*. January 1993. Prepared for the American Nuclear Society International High Level Radioactive Waste Management Conference, April 26-30, 1993. Lawrence Livermore National Laboratory.

DOE. 1988. *Site Characterization Plan, Vol. III, Part A. (Modified from SNL 1987)*. December 1988. Washington, D.C.

DOE. 1991. *Yucca Mountain Site Characterization Project, Title I, Design Summary Report, Vol. 3, Design Drawings*. September 3, 1991. Washington, D.C.

DOE. 1992. *OCRWM Contractor FTE by Program Area and Location*, handout from joint OCRWM/M&O Program Management Review meeting, December 3, 1992. Las Vegas, Nevada.

DOE. 1993. *Critical Path Network NEWESF*. May 20, 1993. Las Vegas, Nevada.

Energy Daily. "Grumbly Takes Stock, Sees Need For Changes." Monday, July 19, 1993, Vol. 21, Nr. 136; p1.

GAO (General Accounting Office). 1993. *Nuclear Waste: Yucca Mountain Project Behind Schedule and Facing Major Scientific Uncertainties*. Report to the Chairman, Subcommittee on Clean Air And Nuclear Regulation, Senate Committee on Environment and Public Works, GAO/RCED-93-124. May 1993. p30.

Gertsch, R. and L. Ozdemir. 1991. *Performance Prediction of Mechanical Excavators in Yucca Mountain Welded Tuffs from Linear Cutter Tests*. Draft report, submitted to Frank Hansen, Sandia National Laboratories. SAND91-7038. Earth Mechanics Institute, Colorado School of Mines, Golden, Colorado.

National Research Council (National Academy of Sciences). 1974. *Better Contracting for Underground Construction*. Report of the Committee on Tunneling Technology. 1974. Washington, D.C.

NWTRB. March 1993. *NWTRB Special Report to Congress and the Secretary of Energy*. March 1993. Washington, D.C.: U.S. Government Printing Office.

NWTRB. March 25, 1993. Letter to Secretary of Energy Hazel R. O'Leary from Nuclear Waste Technical Review Board Chairman John E. Cantlon. March 25, 1993.

NWTRB. August 1993. Memorandum to Lake Barrett, Acting Director of OCRWM from Nuclear Waste Technical Review Board Executive Director William Barnard. August 17, 1993.

OCRWM. 1993. *ESF Changes Under Consideration*. Presentation before the NWTRB by Robert Sandifer, MGDS Development Manager, July 13-14, 1993.

REECO (Reynolds Electrical and Engineering Company). 1992. *123 Yucca Mountain Project, 1.2.3 Drilling Schedule*. May 16, 1992. Las Vegas, Nevada.

RSN (Raytheon Services Nevada). 1991. *ESF Ramp Gradient*. Presentation before the NWTRB by Bruce Stanley, Lead Mining Engineer, September 18, 1991. Las Vegas, Nevada.

RSN. 1992. *Exploratory Studies Facility: Revised Title I Construction Cost Estimate*. Report prepared for the Yucca Mountain Site Characterization Project Office. July 1992. Las Vegas, Nevada.

SNL (Sandia National Laboratories). 1991. *Exploratory Studies Facility Alternatives Study: Final Report*. SAND 91-0025. September 1991. Albuquerque, N.M.

Sperry, P. 1993. Letter report to the NWTRB on *DOE 50% Design Review of ESF Design Package 2*, April 23, 1993.

TRW Environmental Safety Systems, Inc. (OCRWM Management and Operating Contractor). 1993. *90% Design Review - Design Package 2A*. July 19, 1993. Las Vegas, Nevada.

U.S. Congress House. 1992. *Conference Report on Making Appropriations for Energy and Water Development for the Fiscal Year Ending September 30, 1993, and for Other Purposes*. 102d Cong., 2d Sess., September 15, 1992. H. Rept. 102-866; p80.

U.S. Congress Senate. 1993. *Committee Report on the Energy and Water Development Appropriation Bill, 1994*. 103d Cong., 1st Sess., September 1993. S. Rept. 103-000; p128.

Wilder, D. 1993. *Waste Package Environment Thermal Tests*. Presentation to the Nuclear Waste Technical Review Board, full Board meeting on Thermal Loading: The Integration of Science and Engineering, July 14, 1993. Official transcripts.

YMPO (Yucca Mountain Site Characterization Project Office). 1991. *Record Memorandum: Risk/Benefit Analysis of Alternative Strategies for Characterizing the Calico Hills Unit at Yucca Mountain, Rev. O.* January 1991. Las Vegas, Nevada.

YMPO. September 1992. *Preliminary Test Planning Package for Support of Pre-Title II Design Studies: Planned Exploratory Studies Facility Tests, 91-5 Rev. O.* September 1992. Las Vegas, Nevada.

YMPO. November 1992. *Draft Final Report: Integrated Test Evaluation Framework for Prioritizing Tests for the Yucca Mountain Site Characterization Project - Reference Notebook*. November 12, 1992. Las Vegas, Nevada.

10 CFR 60 (Code of Federal Regulations). 1993. Title 10, *Energy*, Part 60, "Disposal of High-Level Radioactive Wastes in Geologic Repositories."