see pocket 6 for enclosure

(45)

Department of Energy
Nevada Operations Office
P. O. Box 14100
Las Vegas, NV 89114-4100

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JUN 07 1985

John J. Linehan
Project Manager
U. S. Nuclear Regulatory Commission
M/S 623-FS
Washington, DC 20555

COMMENTS ON THE NEVADA NUCLEAR WASTE STORAGE INVESTIGATIONS (NNWSI) EXPLORATORY SHAFT CONCEPTUAL DESIGN REPORT (LA-9179-MS)

This letter provides you with our response to the Nuclear Regulatory Commission (NRC) comments on the NNWSI Exploratory Shaft Conceptual Design Report (LA-9179-MS). This material is to be used in preparation for the future site specific workshop on exploratory shaft design.

The NRC letter of April 14, 1983, expressed two broad concerns:

1. "that the site characterization activities will not compromise subsequent long term isolation and containment capabilities of the repository," and

2. "that plans for construction of the exploratory shaft will not preclude the acquisition of adequate information for site characterization."

Subsequent design changes in the NNWSI Exploratory Shaft Program have addressed both of these concerns as they relate to the exploratory shaft and its role in the site characterization process.

With regard to NRC's concern about isolation capabilities of the repository, the most significant change from the 1982 design is that the repository will be in the unsaturated zone (that is, above the water table). This situation greatly reduces the potential for significant groundwater entry into the repository via the exploratory and other shafts. Consequently, the concern over shaft sealing is limited to controlling the movement of surface waters down the shafts. Because the NNWSI proposed repository is located in a semiarid environment, the availability of surface water is quite limited. These consideration lead us to the conclusion that adequately sealing shafts in the unsaturated zone at the NNWSI site will be considerably less complicated than sealing would be in the saturated zone. We have reviewed the transport mechanisms and have not identified any that the Exploratory Shaft Facility perturbs which would compromise the isolation potential of the site. Therefore, it is our view that the construction of the Exploratory Shafts is <u>not</u> an activity that impacts radiological health and safety of the public.

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With regard to NRC's concern about acquisition of information during exploratory shaft construction, the following changes from the 1982 design should be noted:

- o Two exploratory shafts will be constructed rather than one.
- o The larger shaft will be sunk using conventional (that is, drill-blast-muck) techniques rather than large hole drilling.
- o Extensive testing is planned during the sinking process for the larger shaft.
- o The underground testing area has been enlarged considerably to accommodate the testing currently proposed to characterize the site

These changes reflect a significantly increased testing program to be conducted and have significantly increased the amount of site characterization information that will be obtained over what was planned at the time the Conceptual Design Report was issued. This test information combined with the information from the surface based test program should be sufficient to determine the suitability of the site.

We recognize that these conclusions are based on preliminary data and as-yet, unverified assumptions. However, exploratory shaft construction activities will not preclude the ability to obtain additional site characterization information if deemed necessary at some future date.

NRC's letter, Coplan to Vieth of April 14, 1983, contained an attachment listing their need for documented information on the Exploratory Shaft. We note that this listing is generic, applying to other sites in which the repository horizon is below the water table (that is, in the saturated zone) as well as to the unsaturated Yucca Mountain site. We believe that several of these information requests are either inappropriate in an unsaturated medium, or have been addressed by changes in the NNWSI Program as discussed above. However, we have developed brief responses (see Enclosure 1) to these NRC information requests to help you understand our current position.

We look forward to discussing these and other topics with the NRC at the exploratory shaft design workshop. In the meantime, please contact me if you have questions regarding this letter or its enclosures.

Donald L. Vieth, Director
Waste Management Project Office

WMPO:DHI-996

Enclosures:
As stated

cc w/encls:
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see ltr to Linehan fm. Vieth 6/7/85
102.2

ENCLOSURE 1

RESPONSE TO NRC COMMENTS TRANSMITTED AS ENCLOSURE 1 TO THE LETTER, COPLAN TO VIETH OF APRIL 14, 1983, ENTITLED "INFORMATION CONSIDERED NECESSARY REGARDING EXPLORATORY SHAFT CONSTRUCTION AND SEALING"

I. SHAFT AND SEAL DESIGN CONSIDERATION

NRC Comment

"Provide an analysis of the potential effects of construction of the exploratory shaft on long-term sealing capabilities of the rock mass and identify factors that determine the nature and extent of such effects."

Response

Performance analysis studies (Ref. 1) have been conducted to determine the impact of the exploratory shaft (S) on the long-term performance of the repository. The conclusions from these studies are the following.

Conclusions

- Ability of the repository to meet NRC and EPA criteria is not significantly affected by the degree of rock damage which can be anticipated near the ES using excavation methods as specified in Enclosure A, or by the quality of the liner. Therefore, from a sealing perspective, public health and safety are not compromised during the post-closure period by the presence of a damaged zone near the ES.

- Surface barriers, shaft plugs, and station plugs in the repository drifts may be used to restrict the volume of surface water entering the waste disposal area. Detailed analyses of the performance of these engineered components will be made to evaluate needed quality levels for their design and construction. Additional areas of the repository, such as the shop area, will be evaluated for their potential to enhance drainage of waters entering the repository.

- Experiments that assess the drainage capability of the Topopah Spring Member will confirm the extent and hydraulic conductivity of the damage zone. Also, experiments to quantify the water inflow from discrete sources (if any) will be conducted. Such experiments remain the highest priority in the sealing program.

NRC Comment

"Describe how the selected excavation technique and shaft design accounts for limitations and uncertainties in long-term sealing considerations."

Response

The above referenced study does address in a conservative manner the assumed rock damage because of excavation. As discussed in the response to the first comment, it appears that long-term sealing is relatively independent of the shaft design and construction techniques. However, it is noted that the construction controls and overbreak recording requirements, called for in the above recommendations, are intended to keep construction overbreak to a reasonable minimum, and document any overbreak that does occur. These data will support the design of the shaft seals if it is determined that seals are to be emplaced in the shaft. The emplacement of such seals is currently not believed to be necessary. As described in Ref. 1 and 2, features such as surface barriers, shaft plugs, and drift station plugs may be used to control the volume of surface water entering the repository waste disposal area. The seals can be designed and constructed very conservatively to account for the limitations and uncertainties in long-term seal performance.

NRC Comment

"Provide design specifications for the shaft construction and show how they deal with factors affecting sealing."

Response

Design specifications for the shaft construction are not yet complete. When they are, they will contain provisions to control and record overbreak from blasting. However, since the ability of the repository to meet NRC and EPA criteria is not significantly affected by the degree of damage expected from construction, it is not necessary to show how the design specifications deal with factors affecting sealing. However, it should be mentioned that hydraulic conductivity will be measured at various distances out from the shaft wall to show the effects of construction damage. These measurements will be useful to determine the validity of the assumption used in Enclosure A.

NRC Comment

"Describe the seal design and materials."

Response

Seal designs and materials being considered for the Yucca Mountain repository are described in the "Repository Sealing Concepts" report, Ref. 2. At the present time, it is not clear which, if any, of these seals will ultimately be required to adequately decommission the repository. However, the ES might reasonably be expected to have the following:

- a shaft cover at the surface,
- an anchor-to-bedrock plug/seal, and
- a station plug at the repository horizon

Between these structures the shaft would be backfilled with suitable materials such as crushed tuff.

NRC Comment

"Discuss the selected locations of any planned explorations or testing to be performed along the length of the shaft. Include discussion of data on sealing characteristics to be gathered and the limitations and uncertainties associated with the data."

Response

Exploration and testing during ES construction is described in the "Exploratory Shaft Test Plan," Ref. 3 from which the following summary is excerpted:

"Eight tests are planned to start ES construction. One of the eight, shaft-wall mapping, photographing, and hand specimen sampling, will be conducted routinely following each blast round as the ES-1 is being sunk.

This test is expected to require two or more hours after each blasting round, depending on the conditions encountered and what additional sampling is required. Large-block sampling for porewater analysis, ^{36}Cl age dating, and geomechanical testing, will follow selected blasting rounds at 15 to 30 locations in the shaft. Another test, unsaturated-zone water sampling, may require several hours or longer, depending on conditions encountered, their significance and actions required for adequate sampling and measurement. The remaining tests initiated during ES construction will be at predetermined depths. They represent nonroutine operations and will require planned pauses in ES-1 shaft-sinking operations of several hours to several days. These tests include (1) vertical and lateral coring to confirm adequacy of geologic and hydrologic conditions before breakout at the 158-m (520-ft) level, the 366-m (1200-ft) level, and the shaft bottom at 451-m (1480-ft); (2) the tests performed in the upper and lower demonstration breakout rooms (DBRs) to assess constructability and stability of repository-sized drifts; (3) shaft convergence tests, between the 158-m (520-ft) and 366-m (1200-ft) breakouts, and (4) permeability tests also at the 158-m and 366-m levels."

"Most of the tests will be conducted at the 366-m (1200-ft) level in drifts located off the lower DBR. However, a few tests will also be performed in the upper DBR, in a drill room at the bottom of the ES-1, and through the ES-1 shaft liner at selected depths."

It is currently planned to perform hydrologic tests at the interface of the Calico Hills and the Topopah Spring units and within the upper few meters of the Calico Hills unit. The purpose of these tests are (1) to investigate whether significant, sustained water flow in fractures is possible between the Topopah Spring and the Calico Hills units and within the zeolitized tuff of Calico Hills and (2) to obtain bulk hydrologic and geochemical properties for water flow within the Calico Hills unit. The depth of ES-1 will be constrained by the minimum thickness of zeolitized tuff that occurs between the prospective repository horizon and the water table. This constraint is based on the assessment of compliance with the performance criteria in 10CFR60 that pre-waste emplacement groundwater travel time along the fastest path of likely radionuclide travel be a minimum of 1000 years. The thickness of the zeolitized tuff in the vicinity of ES-1, based on data from USW-G4 (Ref. 4) is substantially thicker than the minimum thickness across the proposed repository block. Thus, ES-1 can penetrate into the zeolitized zone and still leave an adequate buffer so that it will not compromise the minimum travel time.

The data collected in these tests will be used in the final design and construction of the shaft seals, which will be emplaced during decommissioning. Of particular significance to seal design and construction will be the extent and nature of the overbreak surrounding the shaft, and the extent of faulting, fracturing, and water producing zones. It is expected that the test results will confirm the present conclusions that the ES construction activities will not significantly impact long-term repository isolation capabilities.

As design and test planning proceed, more detailed information will become available regarding the data to be gathered during ES construction, and how the data will be evaluated and related to seal design and construction activities. Detailed information on test plans will be provided to the NRC when Revision 1 of the Draft Test Plan (Ref. 3) is completed. Reference 3 will be used as the basis for the upcoming workshop with the NRC tentatively scheduled for September 1985.

NRC Comment

"Provide drilling history and results of geotechnical testing from the principal borehole, G-4"

Response

A general description of the principal borehole, USW G-4, along with the generalized stratigraphic log is provided in Ref. 2 (page 69). Reference 4 provides preliminary geologic and geophysical data derived from USW G-4.

II. CONSTRUCTION PLANS AND PROCEDURES

NRC Comment

"Identify the acceptance criteria for construction of the exploratory shaft."

Response

Enclosure B provides a summary description of the construction and testing operations for the ESF. Specific acceptance criteria for the ES are still being developed. However, it is felt that these criteria and their implementing construction controls need be no stricter from a sealing perspective than those required for short-term stability. Therefore, these criteria will be representative of good quality, state-of-the-art conventional shaft construction practices. We anticipate that elaborate quality assurance activities will not be necessary during construction of the ES.

NRC Comment

"Identify procedures used to minimize damage to the rock mass penetrated."

Response

Short-term stability and safety requirements suggest the use of excavation procedures as specified in Enclosure A will be adequate. These procedures limit the damage to the penetrated rock mass to reasonable levels. It is noted that some damage to the penetrated rock mass will occur due to stress relief even if no blasting were used. In view of the insignificant impact of the potential damage on the long term repository performance, it is anticipated that the procedures to control blasting will be typical of good commercial practice.

NRC Comment

"Identify liner construction and placement technique. Include such information as: liner type, liner material testing, and placement of liner. This information needs to be fully considered in application of any permanent sealing program."

Response

A summary of the shaft and liner construction is presented in Enclosure B. It should be stated that the liner materials being considered at this time have not been selected from a long-term sealing point of view. However, the construction methods will not preclude the removal of the liner and surrounding rock out to undisturbed rock, if in the future it is determined to be necessary to emplace suitable sealing components.

III. SEALING OR GROUTING PLANS AND PROCEDURES

NRC Comment

"Describe how the seals are expected to perform in sealing the exploratory shaft. Describe tests done, both laboratory and field, to determine their long-term durability and their compatibility, both chemical and physical, to the host rock environment."

Response

The performance requirements for long-term repository sealing at the Yucca Mountain site are expected to be minimal based on the performance analysis to date (Ref. 1). Sealing concepts are discussed in the "Repository Sealing Concepts" report (Ref. 2). The "Repository Sealing Plan" (Ref. 5) discusses the program underway to verify the adequacy of these seals at the Yucca Mountain site. In view of the limited nature of the sealing situation at Yucca Mountain, and the time prior to decommissioning in which to develop and test seals, we are confident that the repository sealing requirements can be met. It is important to note that the design requirements are under development and will be continually modified as appropriate before construction authorization application.

NRC Comment

"Describe the placement methods."

Response

Seal placement methods have not yet been developed pending establishment of the design requirements for sealing components. As more information is developed, it can be made available, if needed.

NRC Comment

"Describe remedial methods to be used if sealing methods are not adequate."

Response

Remedial methods for failure of long-term seals placed during decommissioning have not yet been developed. Given the minimal nature of the sealing situation at Yucca Mountain, significant remedial action is not anticipated.

IV. CONSTRUCTION TESTING AND INSPECTION PLANS AND PROCEDURES

NRC Comment

"Describe test and inspection procedures to be used during excavation (e.g., plumbness of hole, rock mass disturbance, etc.) to determine acceptability of the shaft as constructed."

Response

Test and inspection activities during ES construction, other than for site characterization purposes, are being developed and specified in the ESF Title II design. They will be consistent with test and inspection procedures for commercial shaft construction practices.

NRC Comment

"Describe test and inspection procedures to be used during shaft liner construction. Include information such as grout injection rates, grout bond logs, thermal measurements of grout during curing, and liner instrumentation to be used.

Response

Test and inspection procedures for the shaft liner are being developed as part of the Title II design for the ESF. They are expected to conform to good commercial practice.

NRC Comment

"Describe test and inspection procedures to be used after sealing of the shaft to assess the results of the sealing effort in controlling adverse effects. Include information such as grout strength tests, visual identification of seal conditions, records of water inflow, assessment of seal bond to host rock, and logging of drill holes."

Response

Test and inspection procedures for seal adequacy after decommissioning have not yet been developed.

NRC Comment

"Described plans to document the above construction activities."

Response

Detailed documentation plans have not yet been finalized for shaft construction activities. However, as a minimum, the Title III summary reports on construction will include summaries of inspection reports, materials testing, lab reports, as-built drawings, changed condition reports, etc. Such plans will be appropriate to the quality assurance category of the ES.

V. PLANS AND PROCEDURES FOR GATHERING SPECIFIC INFORMATION RELATED TO SITE CHARACTERIZATION

NRC Comment

"Describe test plans and procedures used to obtain adequate data on site characteristics that can be measured either directly or indirectly during construction of the exploratory shaft. For example:

- o Geologic mapping and rock mass characterization of the shaft walls
- o Measurements of rates and quantities of groundwater inflow and collection of groundwater samples for testing
- o Measurements of overbreakage during blasting
- o Rock mechanics testing of samples obtained during drill and blast operations."

Response

Plans for gathering data during ES construction are summarized in Section I above and discussed in Reference 3. Detailed procedures for this data gathering have not yet been completed. When completed they can be made available, if necessary.

VI. QUALITY ASSURANCE (QA)

Administrative Procedures

NRC Comment

"Identify the line of responsibility for implementing QA procedures down to and including the Construction Contractor."

Response

The line of responsibility starts with DOE/HQ, who has mandated to DOE/NV that quality practices will conform to ANSI/ASME NQA-1-1983. DOE/NV has in turn written and issued NVO-196-17, entitled Nevada Nuclear Waste Storage Investigations Quality Assurance Plan, which conforms to ANSI/ASME NQA-1-1983. NVO-196-17 requires that each organization participating in the NNWSI write a Quality Assurance Program Plan plus write (or cite) detailed procedures for all items or activities judged to be quality Level I or II. Reynolds Electrical and Engineering Co. (REECo) will be the construction contractor for the ESF; however, the shaft sinking and underground drifting will be performed by a subcontractor. Therefore, the line of responsibility flows from DOE/HQ to DOE/NV to participating organizations and, in the case of REECo, on to the shaft sinking subcontractor. Quality assurance procedures for the Level I and II shaft sinking and drift mining activities will be either written or adopted from such professional societies as ASME, IEEE, AIME, ASCE, etc. These procedures will be part of the subcontract.

NRC Comment

"Identify the procedures to be used by the Quality Assurance organization for implementing and monitoring the QA program for exploratory shaft design, construction, and testing."

Response

Quality assurance procedures for ES construction and testing have not yet been completed. They will be available when completed.

Discussion of QA for ES Design

To understand the quality procedures that were applied to the design of the ESF, it is first necessary to understand the following:

1. The NNWSI Project plans to sink two shafts. No radioactive or radioactively contaminated material will be placed in, or transported through, either of the shafts. This is because (1) there will be no radioactive material involved in the ESF testing program and (2) at the completion of ESF testing, the shafts and underground excavations will be stripped of all internals, utilities, conveyances, and hoisting systems. The two shafts may serve the repository as fresh air intake ducts.

2. The ESF and the repository will be above the water table.

Following is an itemized list of the NNWSI systems and an explanation of their anticipated quality levels:

Liner - The design of the shaft liners is considered to be quality Level II based upon industrial safety requirements. The liner will be designed and constructed in such a way that it can be removed, if necessary, to enlarge the shafts for repository use or removed totally or in part, for emplacement of repository sealing components. Since respository sealing requirements for a repository at Yucca Mountain have not been confirmed, the liner will not be designed or installed to meet repository containment or isolation requirements. However, the liner as now designed will not preclude the installation of suitable sealing components at some future time.

Seals - The design of shaft and borehole seals would be quality Level I. This is based upon the idea that a faulty seal could result in any water travelling down the shaft, reaching the repository level and possibly contributing to a subsequent release of radioactive material to the environment, which could affect the general public. The seals are considered to be part of the repository and they are not designed at this point in time. However, no difficulty is anticipated in designing the seals to meet the required safety standards. As stated before, Reference 1 indicates that sealing of ES-1 and ES-2 will not be a serious problem.

Ventilation - The design of the ventilation system in ES-1, ES-2, and the underground excavations, is considered a quality Level II item, based on industrial safety requirements. In the event of a fire, failure of the system could affect worker safety. The ESF ventilation components are not intended to be used in a repository.

Dewatering - Because the NNWSI ESF and repository will both be built above the water table, the constant threat of flooding from formation water inflows will not exist. Water from drilling operations will be pumped to the surface, but the use of drilling fluids is to be held to a very minimum. Quality Level III is considered adequate for the design of the dewatering system.

Hoist - The hoisting systems design is quality Level II, based on industrial safety requirements. Failure of the system could affect worker safety; the general public is at no risk should the hoisting system fail. The hoisting system will not be used in the repository.

Lighting - Failure of the lighting system during construction and testing activities will only be an inconvenience. All underground personnel are required by law to wear miners lamps. Following construction (during testing operations), the underground area will be equipped with battery-powered emergency lights, to assist personnel until the emergency generators on the surface can be brought on-line. Because of the redundancy built into the ESF lighting systems, their design can be made quality Level III.

Fire Protection - The ESF underground facility will contain very little combustible material. ES-1, ES-2, and the underground excavations will have no fire protection systems, other than smoke detectors and portable (or mobile) fire extinguishers. There are several sprinkler systems in buildings on the surface. A fire in the underground during construction and/or testing could endanger worker life and health, but it would not affect the public, waste isolation, or retrievability. Site characterization data that had been collected, but not yet backed up on magnetic tape on the surface, might be lost, but would not result in faulty data. The lost data would have to be recollected (to the last data backup point). Test apparatus conceivably could be lost. After the shafts are stripped of utilities, internals, etc., the amount of combustible material will be even less.

Rock Structure & Support - Isolated falls of ground from face, back and rib could endanger worker life and health, but it would not affect the public, waste isolation, or retrievability. The design of the underground structure and support is considered quality Level II. Current plans call for radioactive waste to be placed well outside the shaft pillars of either shaft.

Electrical - Loss of electrical power during construction will be an inconvenience, until the emergency generators can be brought on-line. Loss of power does not necessarily constitute an emergency. However, in an emergency, personnel can be hoisted to the surface by one of two routes (ES-1 or ES-2) as soon as the emergency generators are brought on-line. During testing the loss of power is again an inconvenience. Between the start of the power outage and the time the generators are producing power, testing personnel will have to cease work. The testing data acquisition system will be continuously powered by two uninterrupted power supplies (UPS). Because of the redundency of the power system, its design is considered to be quality Level III.

Communications - Communications in the underground of the NNWSI ESF during construction will be accomplished with a mine hoist telephone system and a shaft bell system. During the testing phase, a public address system, a conventional telephone system, and an intercom system will be added. Because of the redundancy in the communications system, its design is considered to be quality Level III.

REFERENCES

1. Letter, T. O. Hunter, SNL, to D. T. Oakley, LANL, "Performance Analysis Studies to be used in Determining Quality Assurance Levels for the Exploratory Shaft Design and Construction Activities," due June 28.

2. Fernandez, M. D. Freshly, 1984, "Repository Sealing Concepts for Nevada Nuclear Waste Storage Investigations Project," SAND83-1778.

3. Draft NNWSI Exploratory Shaft Test Plan (Rev 1) - - (in preparation).

4. R. W. Spengler, M. P. Chornack, 1984, "Startigraphic and Structural Characteristics of Volcanic Rocks in Borehole USW-G4, Yucca Mountain, Nye County, Nevada" USGS-OFR-84-789.

5. J. A. Frenandez, 1985, "Repository Sealing Plan for the Nevada Nuclear Waste Storage Investigations Project, Fiscal years 1984 through 1990," SAND84-0910.

ENCLOSURES

Enclosure A - Specification 02310, Excavation
Enclosure B - Construction and Testing Operations of the Exploratory Shaft Facility

Enclosure A

U.S. DEPARTMENT OF ENERGY

NNWSI ESF PROJECT

TECHNICAL SPECIFICATION

DIVISION 2--SITE WORK

SPECIFICATION 02310
EXCAVATION

PRELIMINARY
NOT TO BE USED FOR
FABRICATION

[illegible]	1	9/8/85	Issued for Approval	[illegible]	[illegible]		[illegible]			
[illegible]	0	8/11/83	Issued for Approval	[illegible]		[illegible]	[illegible]		[illegible] 8/19	[illegible]
[illegible]	0	7/11/83	Issued for Review	[illegible]						
[illegible]	0	5/19/83	Issued for Approval	[illegible]		[illegible]	[illegible]		[illegible]	
OR	REV. NO.	DATE	ISSUED FOR PROGRESS REVIEW	BY	CHK'D	SUPV.	QA	SFTY	LANL	DOE

			DOCUMENT NO.	REV.
	FENIX & SCISSON, INC.	SPECIFICATION	02310	1

U.S. DEPARTMENT OF ENERGY
NNWSI USW ES-1
TECHNICAL SPECIFICATION
DIVISION 2--SITE WORK

SPECIFICATION 02310
EXCAVATION

TABLE OF CONTENTS

1.0 Scope--Shaft and Station

1.1 Description of Work

1.1.1 This specification covers the excavation of an exploratory shaft and the excavation and support of the shaft stations and several test facilities located in or adjacent to the shaft wall lining.

1.1.2 The work to be performed includes, but is not limited to, the following:

a. Excavate a vertical shaft from the collar to a point about 1480 feet below the collar elevation as shown on Drawing M3312-16 and line the excavated shaft from the collar elevation to about 1480 feet below.

b. Excavate and support the shaft to the limits shown on Drawings M3312-16, M3312-17, M3312-18, 3312-29, M3312-29-03, and M3312-38.

c. Excavate and support the test facilities as shown on Drawings M3312-26, M3312-27, M3312-33-01, M3312-34.

1.2 Related Work Specified Elsewhere

1.2.1 Specification 023221--Shaft Concrete Lining

2.0 Applicable Documents

2.1 Codes, Specifications, and Standards

Codes, specifications, and standards referred to by number or title shall form a part of this specification.

2.1.1 The Quality Assurance requirements included in this specification shall be applied in accordance with the relevant elements of the Quality Assurance Program Plan for the Exploratory Shaft at Yucca Mountain, NVO-196-17 rev. 3.

2.1.2 CFR, Title 30, Part 57--Health and Safety Standards--Metal and

Non-Metallic Underground Mines

2.2 U.S. DOE NTS Standard Construction Specifications, Section 1. Earthwork, Parts 1.4.3, 1.5, 1.6, and 1.7.

3.0 Field Execution

3.1 Excavation

3.1.1 Excavate the shaft and proceed and conform to the limits of Drawing M3312-16.

3.1.2 Monitoring & Control of Blasting--The Contractor will measure peak particle velocity resulting from blasting in the shaft with a seismograph and report the results to the Subcontractor. Peak particle velocity shall not exceed 2.0 inches per second which is the safe blasting criterion for structures recommended by the U.S. Bureau of Mines. Should this limit be exceeded and damage occur to Government property the Subcontractor shall repair or make good such damage at his expense.

3.1.3 Excavation Procedure--Overbreak or overexcavation beyond the limits shown in the drawings shall be minimized to practical limits. The Contractor may specify that the Subcontractor modify his excavation and lining procedure if evidence is produced which indicates that unacceptable conditions are being created.

3.1.2.1 The Subcontractor shall use "smooth blasting" technique to excavate the shaft from depth 110 feet to 240 feet, from depth 1350 feet to shaft bottom and to excavate the shaft through the station zones shown on the drawings to the extent practicable. Smooth blasting technique is defined in such publications as the

E.I. Dupont Blaster's Handbook 1978 ed. See attached excerpt.

3.1.4 Unacceptable conditions resulting from the Subcontractor's excavation procedure include, but are not limited to:

a. Shaft wall conditions preventing scientific investigation.

b. Unsafe conditions for personnel.

c. Endangerment of, or damage to, completed work.

3.1.5 The Subcontractor shall scale down and clean the shaft wall after each 7 feet of excavation advance so that scientific investigations can be made prior to placement of the shaft lining.

3.1.6 Excavated material shall be disposed of by dumping with an end loader into the area shown on Drawing JS-025-055-C3 in accordance with NTS Standard Specification 1.4.3.

4.0 Submittal of Documents

Documents shall be submitted in accordance with the attached form: Document and Distribution Requirements.

5.0 Attachments

The attachments on the following pages are part of this specification.

(1) CONTRACTING OFFICER	(2) SUPPLIER OF EQUIPMENT/MATERIAL FILES. FILES TO BE AVAILABLE TO CONTRACTING OFFICER INSPECTOR. FILES DISPOSITION TO BE AS DIRECTED BY THE CONTRACTING OFFICER.	REPRODUCIBLE COPIES OF DOCUMENTS SHALL BE FURNISHED IN QUANTITIES SHOWN AND DISTRIBUTED ACCORDING TO THE FOLLOWING CODE PRIOR TO: F - FABRICATION, C - CONSTRUCTION/INSTALLATION, S - SHIPMENT, A - FINAL ACCEPTANCE. EXAMPLE: 1F - 1 COPY PRIOR TO FABRICATION

ITEM	DOCUMENT REQUIREMENTS	DOCUMENT NUMBER & PARAGRAPH NUMBER WHERE DATA REQ'T IS SPECIFIED	COPIES FOR REVIEW TO (1)	COPIES FOR REVIEW TO	COPIES FOR VERIFICATION BY INSPECTOR AT (2)	RECORD COPIES TO (1)	RECORD COPIES TO
1	F&S Shaft Inspectors Report		1A			1A	

A DOCUMENTATION PACKAGE SHALL BE PRESENTED TO THE INSPECTOR FOR REVIEW AND SIGN-OFF PRIOR TO SHIPMENT AND SHALL CONTAIN THOSE DOCUMENTS THAT HAVE BEEN PREVIOUSLY APPROVED BY THE CONTRACTING OFFICER, AS WELL AS THOSE REQUIRED FOR THE CONTRACTING OFFICER'S INSPECTOR.

DESCRIPTION	ORIG. ENGR.	ENGR. SUP.	PQAS	PROJ. ENGR.	DATE	DOCUMENTATION AND DISTRIBUTION REQUIREMENTS	SPECIFICATION NUMBER	REV.
REISSUED FOR APPROVAL							02310	0
ISSUED FOR APPROVAL								
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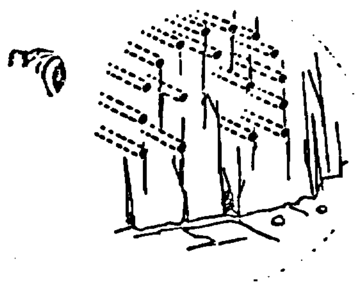


SMOOTH BLASTING

Principle

Smooth Blasting, sometimes referred to as Contour Blasting, Perimeter Blasting or Sculpture Blasting, was introduced in Sweden and is the most widely accepted method for controlling overbreak in underground headings and stopes. Smooth blasting techniques, as described by Ulf Langefors and Björn Kihlström in their recent book "The Modern Technique of Rock Blasting," have application in both underground and open work. However, since the use of this technique in open work is for all practical purposes identical to Cushion Blasting, only its application to underground work will be covered in this report.

The basic principle of smooth blasting is the same as that for Cushion Blasting: holes are drilled along the excavation limits and are lightly loaded to remove the final berm. By shooting with minimum delay between the holes, a shearing action is obtained which gives smooth walls with minimum overbreak.

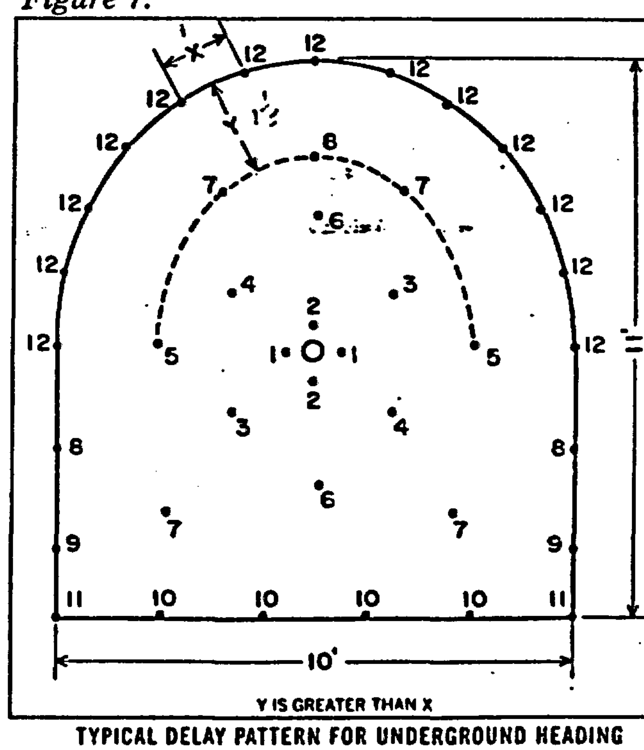
Application

Underground Work—In underground headings where the back and ribs slough and cave because of unconsolidated material, overbreak is common due to the shattering action from the blasting.

By employing the smooth blasting technique with light, well distributed explosive loads in the perimeter holes, fewer supports are required and less overbreak occurs. Even in harder more homogeneous formations, smooth blasting provides smoother and firmer backs and ribs.

Smooth blasting in underground work involves perimeter holes drilled on a burden-to-spacing ratio of approximately 1½-to-1, loaded with light, well distributed charges, and fired with the last delay period in the round (See Figure 7). These holes are fired after the lifter holes to insure that the broken rock is displaced sufficiently to offer maximum relief for the smooth blast holes. This relief permits unrestricted movement of the final berm and results in less shatter beyond the excavation limit. To insure maximum relief, a pilot heading is sometimes used. After the pilot heading has been completely excavated, the final berm is drilled and shot. In this case, depths greater than the length of a single round can be smooth blasted. The pilot heading method allows the use of smooth blasting around a greater portion of the periphery of a heading. When shooting smooth blast holes in a round as shown in Figure 7, the confinement relief is limited to the arch and partially down the rib due to muck pile-up. Therefore, good smooth blasting results generally are not obtained lower in the ribs.

Figure 7.



TYPICAL DELAY PATTERN FOR UNDERGROUND HEADING

Although the 1½-to-1 burden-spacing relationship is recommended as a starting point, the formation being blasted may warrant modifications. Also, firing the smooth blast holes with minimum delay between holes is not always necessary. The well-distributed light loads in the perimeter holes with conventional patterns and delays have often produced satisfactory results. Table II gives the recommended patterns and loads/ft. for smooth blasting.

Since it is not convenient or practical to attach charges to "Primacord" lines in horizontal holes, smooth blasting is usually done by string loading small diameter cartridges of low density dynamite to obtain the light loads as well as good distribution throughout the hole. It is necessary to plug these holes with tamping plugs, clay or even a tamped cartridge of the standard sized dynamite. If the smooth blast holes are not plugged, the string-loaded charges will be sucked out from the previous delayed holes. Plugging also prevents excessive rifling and permits the use of lighter charges.

Long, small-diameter cartridges of low density explosives give good powder distribution throughout the length of the borehole. However, standard 8" long cartridges of standard diameter have been used successfully in underground smooth blasting work when spacers were employed between cartridges to give a low over-all concentration of load (lb./ft.). This technique, however, does result in relatively high point concentrations and can give inferior results in unconsolidated formations.

Figures 8 and 9 show results of the application of smooth blasting.

TABLE II—SMOOTH BLASTING

Hole Dia. Inches	Spacing* Ft.	Burden* Ft.	Explosive Charge* Lb./Ft.
1½-1¾	2	3	.12-.25
2	2½	3½	.12-.25

**Dependent upon formation being shot. Figures given are an average.*

Advantages

Smooth blasting has two principal advantages:

- Reduces overbreak from conventional methods.
- Requires less back supports.

Limitations

There are two basic limitations to smooth blasting:

- Usually involves more perimeter holes than conventional method.
- Will not work in all formations. If the ground is too weak to support itself, smooth blasting will not completely eliminate need for back supports.

Figure 8.

SMOOTH BLASTING RESULTS IN UNDERGROUND HEADING

Figure 9.

SMOOTH BLASTING TO REQUIRED CONTOURS

From "The Modern Technique of Rock Blasting" (John Wiley & Sons, Inc. New York, 1963) Courtesy Ulf Langefors

6.0 CONSTRUCTION AND TESTING OPERATIONS OF THE EXPLORATORY SHAFT FACILITY

6.1 Introduction

This chapter is intended to provide the reader with a general understanding of the mining activities that will be required to construct the Exploratory Shaft Facility (ESF), to show the probable sequence of those activities, and to describe briefly the tests that will be performed during the construction period. It is important to recognize that the sole purpose of the ESF is to support the planned in situ testing, and, therefore, the design and construction methods have been developed specifically to that end. However, should the site ever be licensed for construction of a repository, the two ESF shafts would probably be incorporated into its design for ventilation (MacDougall, 1984).

The ESF will consist of

- the ES-1 shaft: 3.66-m (12-ft) finished inside diameter, to a depth of ~451 m (1480 ft);
- a landing and a test drift at the 158-m (520-ft) level;
- a landing and ~396 m (1300 ft) of drifts and rooms at the 366-m (1200-ft) level;
- a drill room at the bottom of the shaft; and
- the ES-2 shaft: 1.83-m (6-ft 4-in.) finished diameter, from the 366-m (1200-ft) level to the surface, for ventilation and emergency egress.

Surface facilities will include the headframes, hoists, power substation, construction and testing support buildings, first-aid trailer, utilities, and access road. A conceptual drawing of the entire facility is shown in Fig. 6-1.

Construction of ES-1 will be by conventional drill-blast-muck mining methods so that the geologic and hydrologic conditions of the penetrated interval can be examined as the shaft is advanced, and to minimize the potential for introducing large quantities of water into the unsaturated-zone rock that is being characterized. (A large-diameter drilled shaft was eliminated from consideration because only minimal testing could be done, and relatively large volumes of drilling fluid would be required using that construction method.) The drifts and rooms are also planned to be mined using drill-blast-muck methods with all rock rubble (muck) carried to the surface via the muck skip in ES-1.

The second shaft, ES-2, will be constructed by drilling a pilot hole to

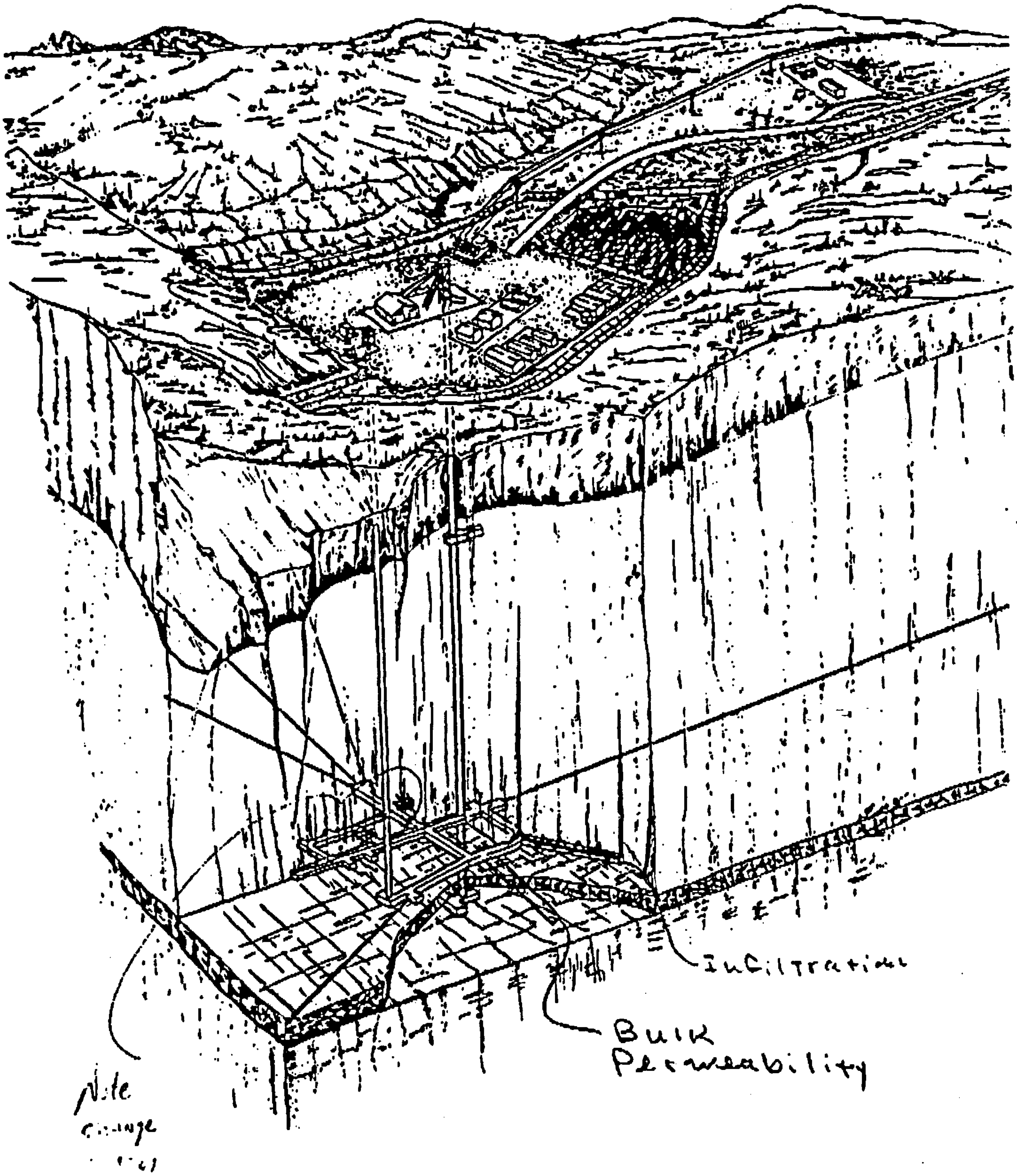


Figure 6-1. Conceptual illustration of the Yucca Mountain ESF.

the 366-m (1200-ft) level, attaching a larger diameter reaming bit at the bottom of the drill string, and then upreaming the shaft back to the surface. Rock cuttings will fall to the bottom and then be removed by LHD to ES-1 and up ES-1 to the surface.

Tests will be conducted in ES-1 proper as well as in and from the drifts and rooms at the three breakout levels (Fig. 6-2) and in the main testing facility at the 366-m (1200-ft) level. At present, no formal tests are planned to be conducted in ES-2, although core and/or cuttings from the pilot hole will be logged and saved, drilling information collected, and at least a caliper log and TV camera survey will be made before emplacing the liner (shotcrete or steel casing are being considered for the ES-2 liner). The data that will be acquired during construction of the ESF include geological (mapping, sampling, etc.), hydrological and water transport (pore- and fracture-water samples, perched-water sampling if perched water is encountered, permeability measurements, etc.), geomechanical (rock strength, in situ stress measurements, convergence measurements around shaft and drifts, thermal response, etc.), and geochemical (water analyses, mineralogy/petrology sampling, etc.).

After construction is completed, a number of other tests will be conducted -- principally in the main ESF drifts and rooms at the 366-m (1200-ft) level. These tests will provide data on the near-field environment around simulated waste canisters, on water infiltration and transport phenomena, on liquid and vapor diffusion, and on rock-mass and fracture permeability. The tests will include core drilling of long lateral holes to examine known structures (faults) and to assess lateral continuity and characteristics of the rock mass. The layout of the main test facility and the locations of the tests planned there are shown in Fig. 6-3.

Much of the data that are to be acquired during ESF testing will be automatically collected and stored by means of a computerized Integrated Data System (IDS). Not only will the IDS take data produced as electrical voltages, currents, or resistances, it will also continually monitor the performance of the test sensors to help assure that the incoming data are valid. Both anomalously high and low signals will be flagged as suspect, and longer range signal trends due to calibration drift or other causes will be monitored. Onsite, the data can be accessed by the investigators and, using available minicomputers, they can convert the raw data to a form that will allow them to check test performance, assess preliminary results, etc. The entire IDS is

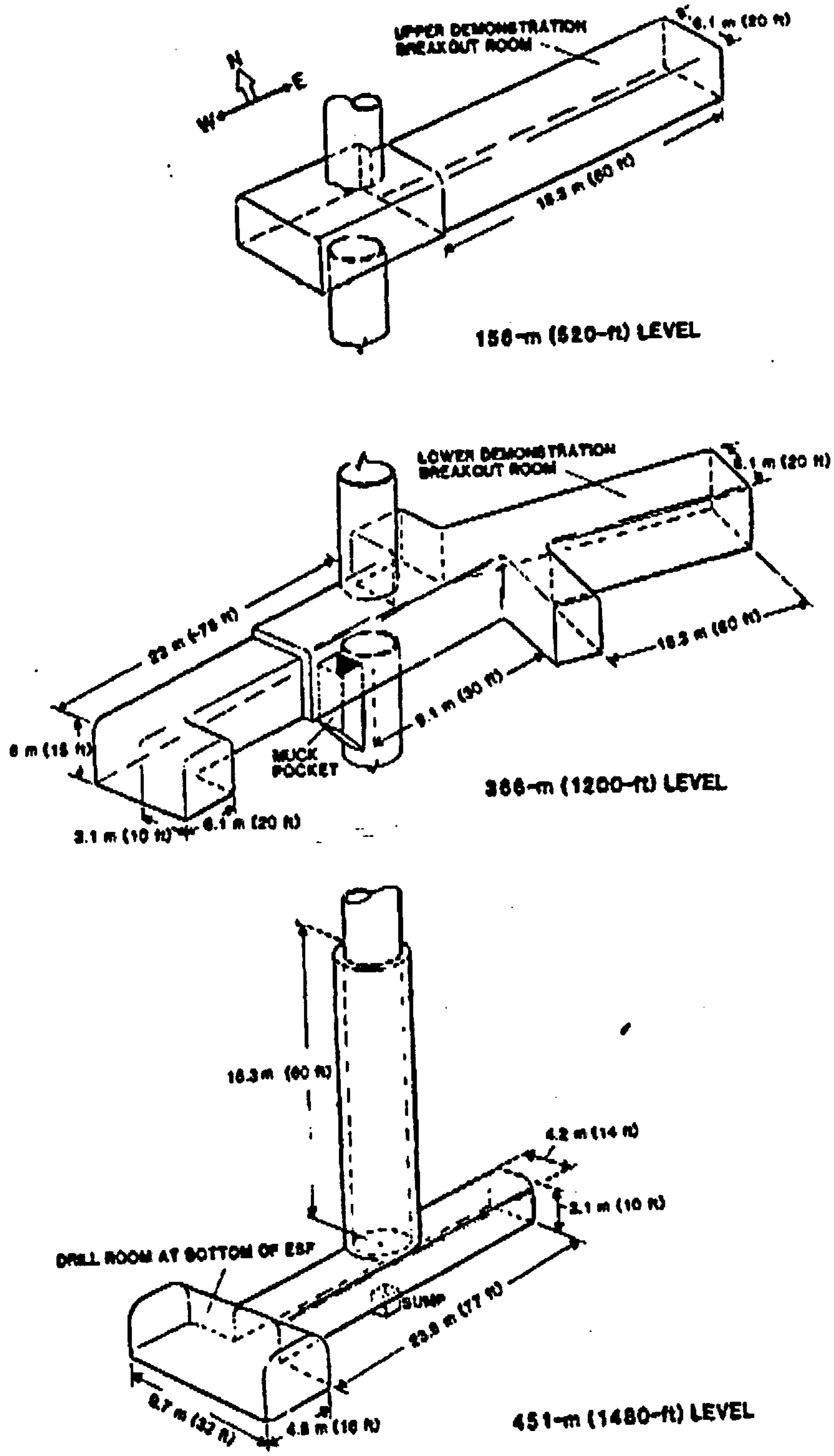


Figure 6-2. Drifts and rooms to be constructed during ESF sinking. Drifts and rooms for the main test facility will be constructed at the 366-m (1200-ft) level off the west end of the landing.

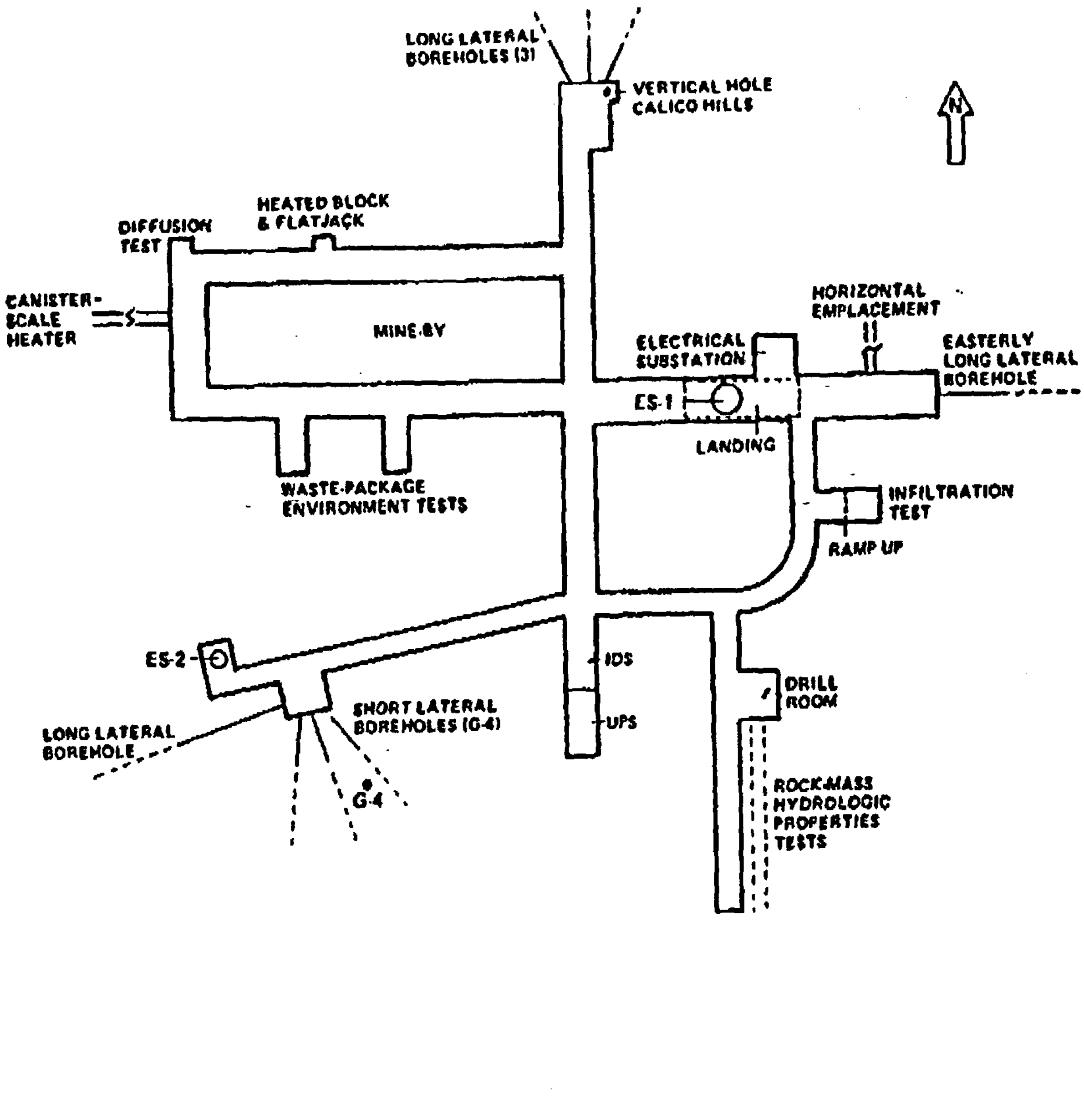


Figure 6-3. Layout of the main test facility.

described in much more detail in Section 6.0, Part II, of this document.

6.2 Sequence of Shaft Construction Operations

The following brief descriptions of construction operations are ordered to generally follow their real-time occurrence as the ESF is developed. As planning becomes more refined, there may be some minor revisions to this construction sequence. The durations for the various activities have been estimated (Table 6-1) but are subject to considerable change due to unexpected conditions encountered while mining, changes in planned tests, labor problems, etc.

TABLE 6-1. CONSTRUCTION SEQUENCE FOR MINING ES-1[a]

Event No.	Activity	Duration (days)[b]
1	Excavate alluvium and install liner plate to 30 ft.	10
1-2	Excavate rock to 60 ft.	5
2-3	Install rebar and forms for collar.	15
3-4	Pour collar 30 ft.	1
2-4	Construct headframe foundation.	10[c]
4-5	Move shaft forms.	2
5-6	Line shaft to 50 ft.	4
6-7	Conduct radial borehole test.	3
7-8	Sink and line shaft to 80 ft.	4
8-9	Install galloway.	3
9-10	Install safety doors.	1
10-11	Erect headframe.	3
11-12	Install ventilation, utilities, communication lines, and rope and check out hoist.	14
12-13	Sink and line shaft to 120 ft.	4
13-14	Conduct radial borehole test.	3

(continued)

[a] Changes in this sequence are probable as plans are updated.

[b] Assumes 3 shifts per day, 7 days per week.

[c] Concurrent activity, not additive to total duration.

TABLE 6-1. CONSTRUCTION SEQUENCE FOR MINING ES-1[a] (continued)

Event No.	Activity	Duration (days)[b]
14-15	Sink and line shaft to 160 ft.	2
15-16	Conduct radial borehole test.	3
16-17	Sink and line shaft to 210 ft.	4
17-18	Conduct radial borehole test.	3
18-19	Sink and line shaft to 240 ft.	4
19-20	Conduct radial borehole test.	3
20-21	Sink and line shaft to 265 ft.	3
21-22	Conduct shaft convergence test.	21
22-23	Sink and line shaft to 450 ft.	18
23-24	Conduct radial borehole test.	3
24-25	Sink and line shaft to 470 ft.	2
25-26	Drill 100-ft vertical core hole.	3
26-27	Sink and line shaft to 520 ft.	5
27-28	Break out at 520-ft level.	7
28-29	Excavate 520-ft station and upper DBR.	14
29-30	Conduct lateral borehole test.	22
30-31	Sink and line shaft to 560 ft., and measure permeability.	4
31-32	Install station steel and concrete.	7
32-33	Sink and line shaft to 650 ft.	10
33-34	Conduct shaft convergence test	21
34-35	Sink and line shaft to 710 ft.	7
35-36	Conduct radial borehole test.	3
36-37	Sink and line shaft to 1050 ft.	38
37-38	Conduct shaft convergence test.	21

(continued)

[a] Changes in this sequence are probable as plans are updated.

[b] Assumes 3 shifts per day, 7 days per week.

[c] Concurrent activity, not additive to total duration.

TABLE 6-1. CONSTRUCTION SEQUENCE FOR MINING ES-1[a] (continued)

Event No.	Activity	Duration (days)[b]
38-39	Sink and line shaft to 1080 ft.	3
39-40	Conduct radial borehole test.	3
40-41	Sink and line shaft to 1150 ft.	8
41-42	Drill 100-ft vertical hole.	3
42-43	Excavate to 1200-ft level.	5
43-44	Conduct lateral borehole test.	22
44-45	Break out at 1200-ft level.	7
45-46	Drive drift 1W to intersection, and drift 1E.	35
46-47	Drill stress permeability holes.	21
47-48	Sink and line shaft to 1230 ft., excavate for muck pocket, and install heavy ground support.	28
48-49	Install station steel, construct loading pocket, install piping and electrical, and pour concrete landing pad.	21
49-50	Install power lines and data conduit to 1200-ft level.	7
50-51	Sink and line shaft to 1300 ft.	8
51-52	Conduct radial borehole test.	3
52-53	Sink and line shaft to 1320 ft.	2
53-54	Conduct radial borehole test.	3
54-55	Sink and line shaft to 1400 ft.	9
55-56	Conduct radial borehole test.	3
56-57	Sink and line shaft to 1460 ft.	2
57-58	Conduct radial borehole test.	3
58-59	Sink and line shaft to 1480 ft.	2
59-60	Break out at 1480 ft.	7

(continued)

[a] Changes in this sequence are probable as plans are updated.
[b] Assumes 3 shifts per day, 7 days per week.
[c] Concurrent activity, not additive to total duration.

TABLE 6-1. CONSTRUCTION SEQUENCE FOR MINING ES-1[a] (continued)

Event No.	Activity	Duration (days)[b]
60-61	Excavate drill room and sump.	21
61-62	Install shaft gates and piping, and pour station concrete.	5
62-63	Remove galloway.	3
63-64	Bolt bulkhead in skip compartment.	3
64-65	Install skip and rope, and limit switches, modify headframe.	5
65-66	Drill 250-ft hole in Calico Hills, develop electrical and substation at 1200-ft. level.	20
	Total	562

[a] Changes in this sequence are probable as plans are updated.
[b] Assumes 3 shifts per day, 7 days per week.
[c] Concurrent activity, not additive to total duration.

6.2.1 Surface Preparations

The actual mining of the ESF will begin after most of the surface preparations and support facilities have been completed. Basically, these will include development and stabilization of a surface pad (~5.85 acres), access roads, and drainage control channels; electrical distribution systems with emergency back-up generators for surface and underground facilities; potable and fire protection water systems; portable shop, warehouse, laboratory, and office buildings; a sanitary sewer system; and a ventilation system for the shaft and test facilities (Fig. 6-4). Concrete pads with covered utility channels and foundation supports will be formed around the ES-1 and ES-2 shaft openings. The headframe on ES-1 will not be erected until after the shaft collar is completed. The ES-2 headframe will not be erected until the upreaming is completed. The purpose of a shaft collar is to stabilize unconsolidated ground at the surface, and to provide a structural anchor into competent bedrock. Covers over the shaft openings at the collar will help keep precipitation and other deleterious material out of the shafts.

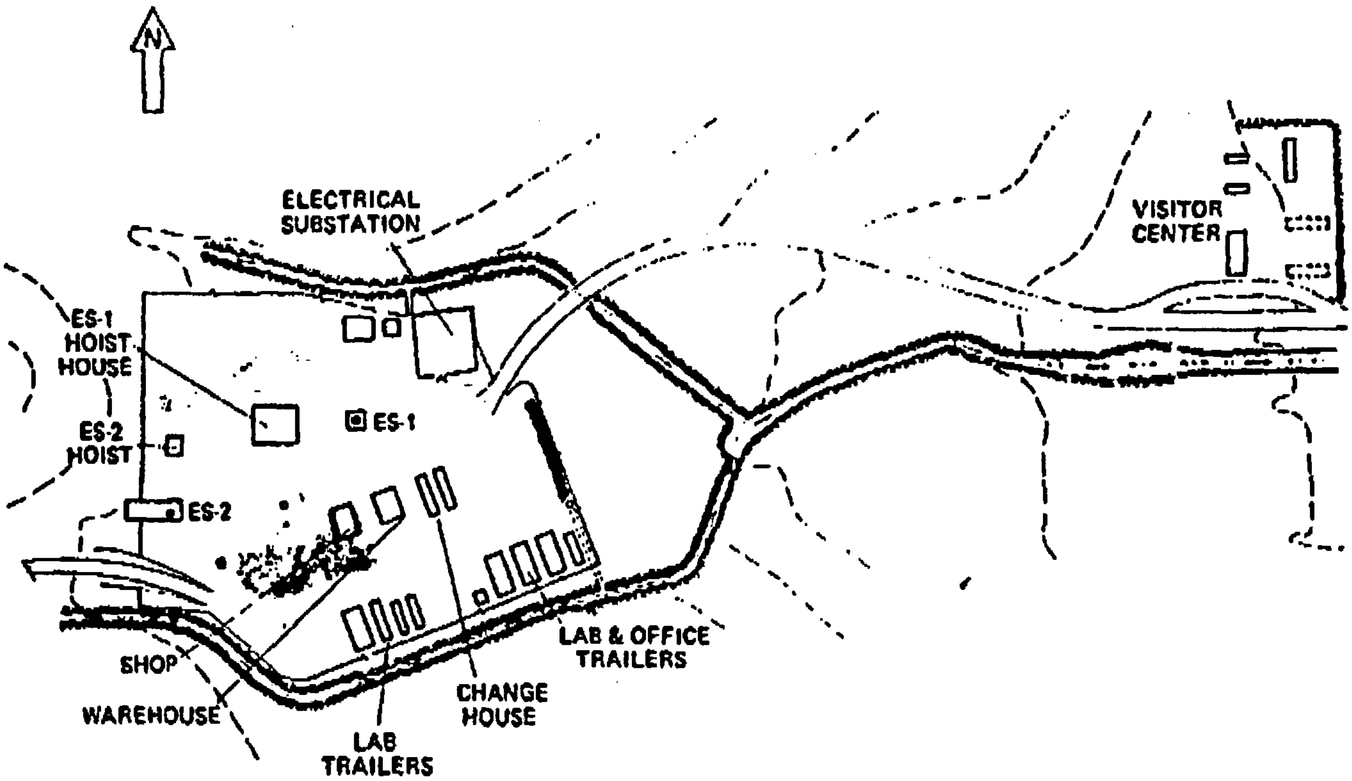


Figure 6-4. General site plan for the ESF.

6.2.2 Shaft Collar Construction

The ES-1 shaft collar includes the uppermost portion of the shaft from the surface just into competent bedrock. It is expected that the combination of fill and unconsolidated alluvium at the ES-1 site on Yucca Mountain will be approximately 10 m (30 ft) deep, with about 3.0 m (10 ft) of this being fill material. The unconsolidated interval at ES-1 will be excavated mechanically by using a crane with clamshell shovel [Fig. 6-5(a) and (b)]. Steel ring liner segments, 4.8 m (16 ft) in diameter by 0.6 m (2 ft) high, will be installed through the unconsolidated zone as excavation proceeds, to control sloughing of loose material into the shaft [Fig. 6-5(c)]. When bedrock is reached, the shaft will be belled out to a diameter of about 6.1 m (20 ft) to provide a secure anchor at the alluvium/hard rock interface [Fig. 6-5(d)].

At this point, the excavation work will temporarily stop while reinforcing steel is installed from the surface to the bell-out in the zone between the 3.7-m (12-ft) finished inside diameter and the 4.8-m (16-ft) to 6.1-m (20-ft) outside diameter of the collar walls. After the reinforcing steel is in place, slip forms will be installed and aligned and then the shaft collar concrete will be poured [Fig. 6-5(e)].

6.2.3 Shaft Collar to Upper DBR

When the ES-1 collar concrete has set up sufficiently, the excavation work will continue, still using the crane for access and muck removal. Jackhammers will probably be used to break up the rock at and slightly below the alluvium/bedrock interface until the shaft penetrates into hard, unweathered bedrock where drill-blast techniques will be required. The shaft diameter will be maintained at just over 4.3 m (14 ft) in order to meet the specified 0.3-m (1-ft) liner-wall thickness. The crane-supported mining will continue to a depth of between 12 and 24 m (40 and 80 ft), with the actual depth determined by the rock conditions and the clearance needed between the sinking deck and shaft bottom to prevent equipment damage caused by blasting at the shaft bottom. Once the necessary depth is reached, shaft excavation will again be halted while the headframe, hoists, sinking deck, etc., are erected and/or rigged up (Fig. 6-6). It is estimated that these activities will require about one month to complete before mining resumes.

After the headframe, sinking deck, and associated equipment are in place, the shaft-sinking operation will become more efficient and, barring unexpected conditions, generally routine down to a depth of about 143 m (470 ft), or

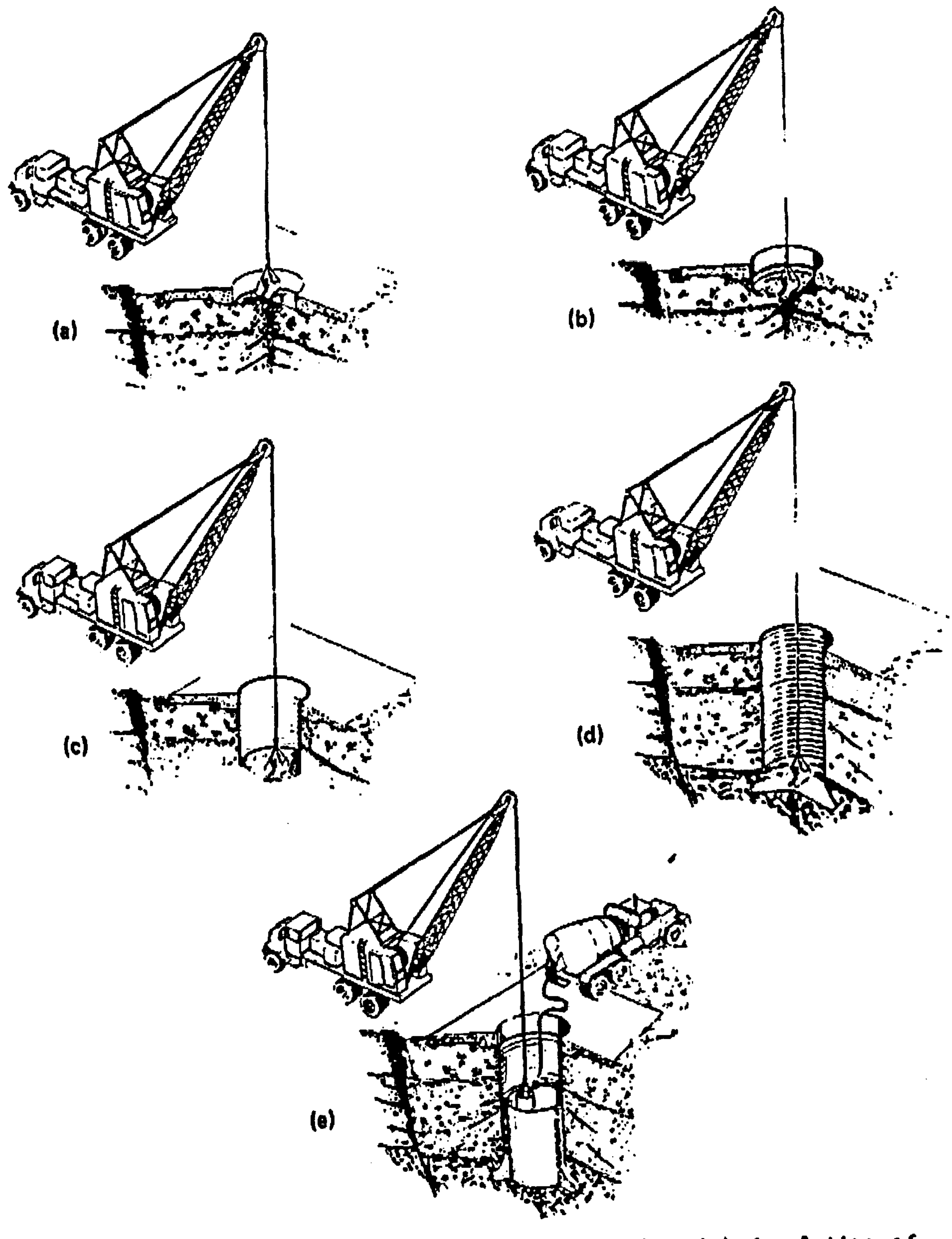


Figure 6-5. ES-1 excavation sequence, 0-10 m (0-30 ft): (a) Completion of concrete pad and start of excavation into unconsolidated fill and alluvium. (b), (c) Excavation through unconsolidated fill and alluvium and installation of 4.8-m (16-ft) steel rings. (d) Bell-out at alluvium/bedrock interface. (e) Slip-forms, reinforcing steel, and start of concrete pour.

about 15 m (50 ft) above the proposed depth of the upper DBR. A typical sequence of operations will consist of drilling in circular patterns a number of small-diameter blast holes 7 to 10 ft into the rock. The number, depth, and location of the holes will be determined based on the rock conditions and previous blasting results. The blast holes will then be loaded with explosives and fused in such a way that the blast is controlled (i.e., to maximize the vertical advance, minimize blast damage to the shaft walls, and produce optimum-sized rock fragments). Once the blast holes are prepared, the sinking deck and associated equipment will be raised to protect them from damage. The miners will then exit the shaft and the explosives will be detonated. Following each blasting round, air will be exhausted for a time to remove smoke, dust, and fumes before the miners enter the shaft to muck out the rubble.

Normally, shaft miners spray the rubble with water for additional dust control before mucking. However, water in the ESF will be used sparingly so as not to adversely impact the hydrologic tests. In fact, all water used in shaft construction, including water used for making liner concrete, will be tagged with a suitable tracer. Water entering the shafts, the humidity in the air supply, and exhaust ventilation air will be metered and recorded. The chlorine content of explosives used in shaft construction will be analyzed and monitored to help identify possible contamination of natural pore waters used for ^{36}Cl age determinations.

Once the miners are back downhole, they will use a mucking machine hung below the sinking deck and a muck bucket operated on the main hoist to remove the rubble (Fig. 6-6). Each blasting round will advance the shaft about 2 m (7 ft). After all rubble has been mucked out and any loose rock cleaned off the walls, the miners will stow their equipment and leave the shaft so the scientists can enter and conduct shaft-wall mapping and other tests in the freshly exposed interval of wall rock.

When the scientists have completed their work, they will exit the shaft and the miners will enter to prepare the next blast round. After each of four blast rounds, but before the last round shot is mucked out, the miners will lower the slip forms for the shaft-wall liner, align them, and pour a 6-m (20-ft) section of concrete liner. Where specified by the scientists, blockouts will be installed to protect extensometer anchors, water seep piping (if present), and pressure-cell instrument lines before the liner is poured. The liner concrete is specified to be at least 1 ft thick, unreinforced (except in

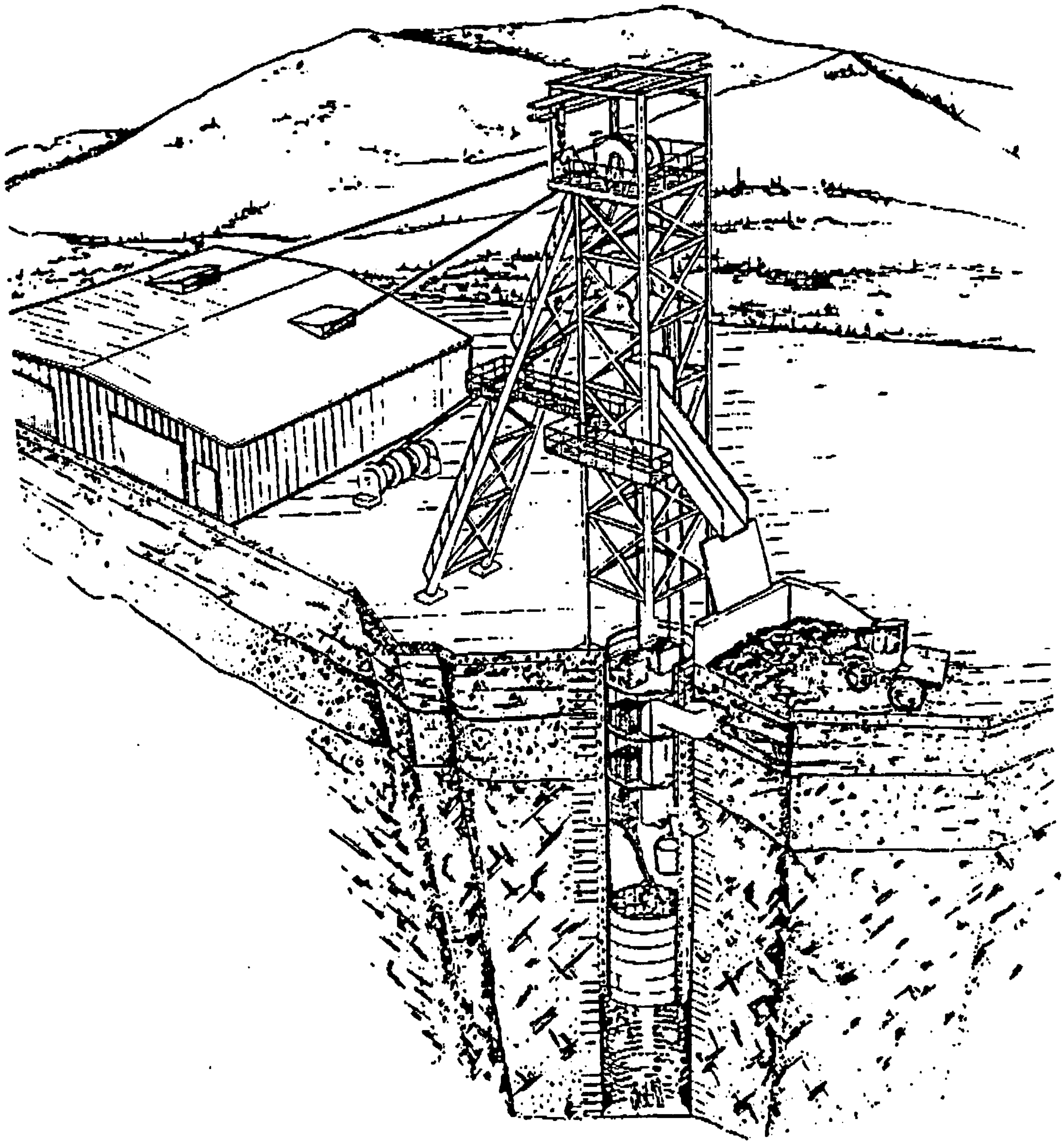


Figure 6-6. Headframe, hoist, and sinking deck for ES-1.

the collar and in the brow intervals above each breakout), and have an unconfined compressive strength of at least 5,000 psi when cured. While the freshly poured concrete is setting up, the miners will move up the shaft 18 m (60 ft) or so and install a 6-m (20-ft) section of shaft internal steel, including manway ladders, skip and cage compartments and hoist guides, utility piping, instrument conduits, etc. (Fig. 6-7). When this work is completed, the miners will move back to the shaft bottom and muck out the rubble remaining from the previous blasting round. The scientists will then conduct their tests, and the sequence of activities will repeat down to about 15 m (50 ft) above the proposed depth of the upper DBR.

At 15 m (50 ft) above the upper DBR, a small drill rig will be lowered to the shaft bottom to air core a centered, small-diameter hole ~30 m (~100 ft) deep (Fig. 6-8, Step 1). Visual examination of the core will be used to tentatively determine the depth at which to break out. At about 6 m (20 ft) above the selected depth (probably at the level where the vertical core drilling is done), the shaft wall will be bolted and reinforced to provide a secure anchor into the bedrock for added support to the reinforced liner interval (brow) immediately above the breakout. The brow will be reinforced with both rock bolts and vertical steel tendon rods set within the concrete from the anchor down to the breakout level. The purpose of the reinforcement is to remove heavy vertical loading on the wall rock at the breakout level so that mining of the upper DBR can proceed safely and with assured long-term stability of the drift opening near the shaft, where stresses concentrate. At the breakout level, small-diameter holes will be air cored laterally into the rock mass adjacent to the shaft to confirm suitable rock conditions (Fig. 6-8, Step 2). If rock conditions are suitable, construction of the upper DBR will begin (Fig. 6-8, Step 3).

6.2.4 Construction of the Upper DBR

Work on the upper DBR will actually include mining two types of rooms: (1) the landing excavated directly off the ES and (2) the upper DBR proper, excavated off the east end of the landing (Fig. 6-2). The landing will provide a reinforced area for off-loading equipment and handling muck produced by upper-DBR construction.

The landing will be mined ~3 m (~12 ft) east and 9 m (30 ft) west from the shaft (Fig. 6-2). The east-west orientation is to be used for convenience because of the fixed position of the headframe and the haulage system within

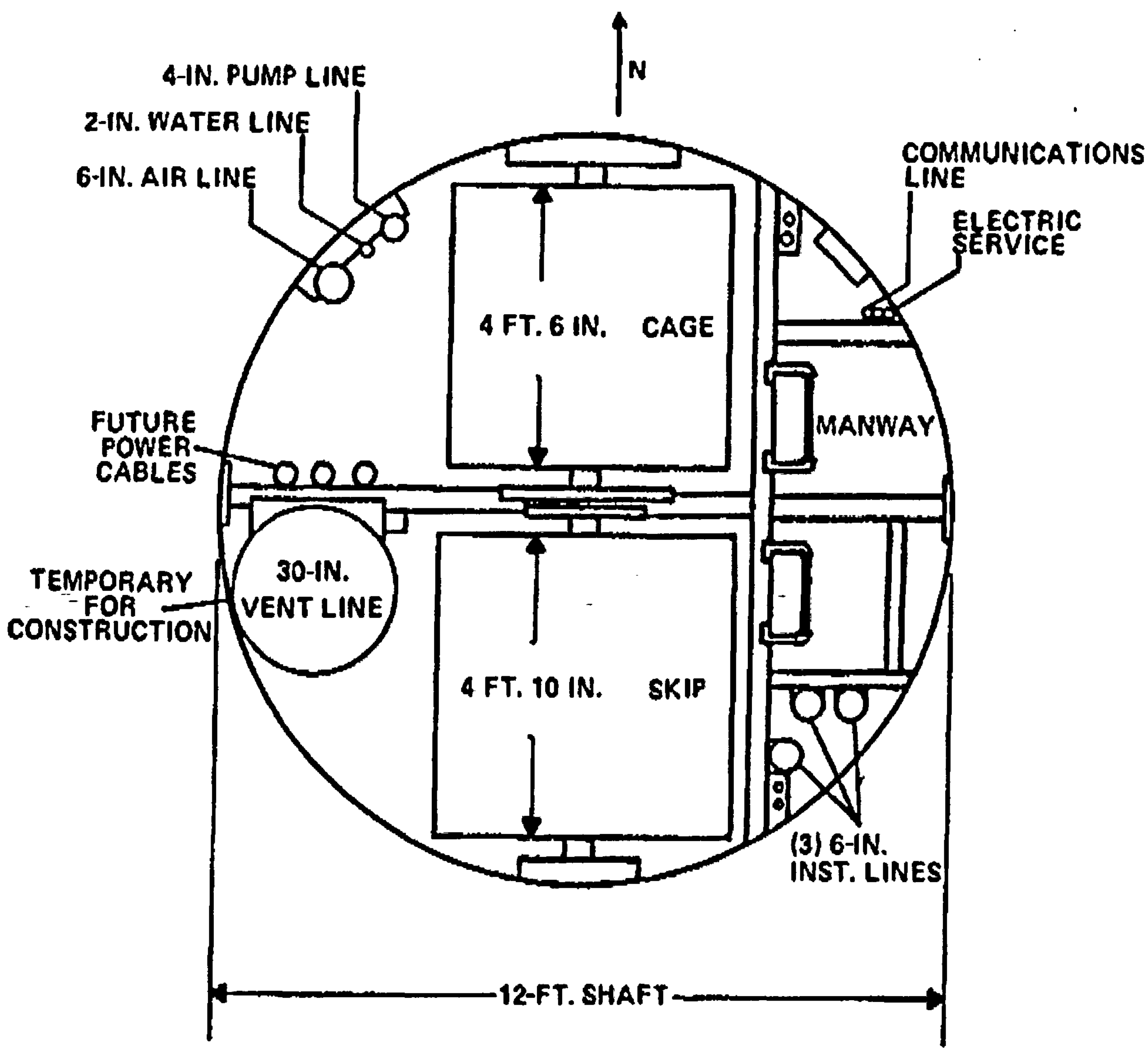


Figure 6-7. ES-1 internal design in cross section.

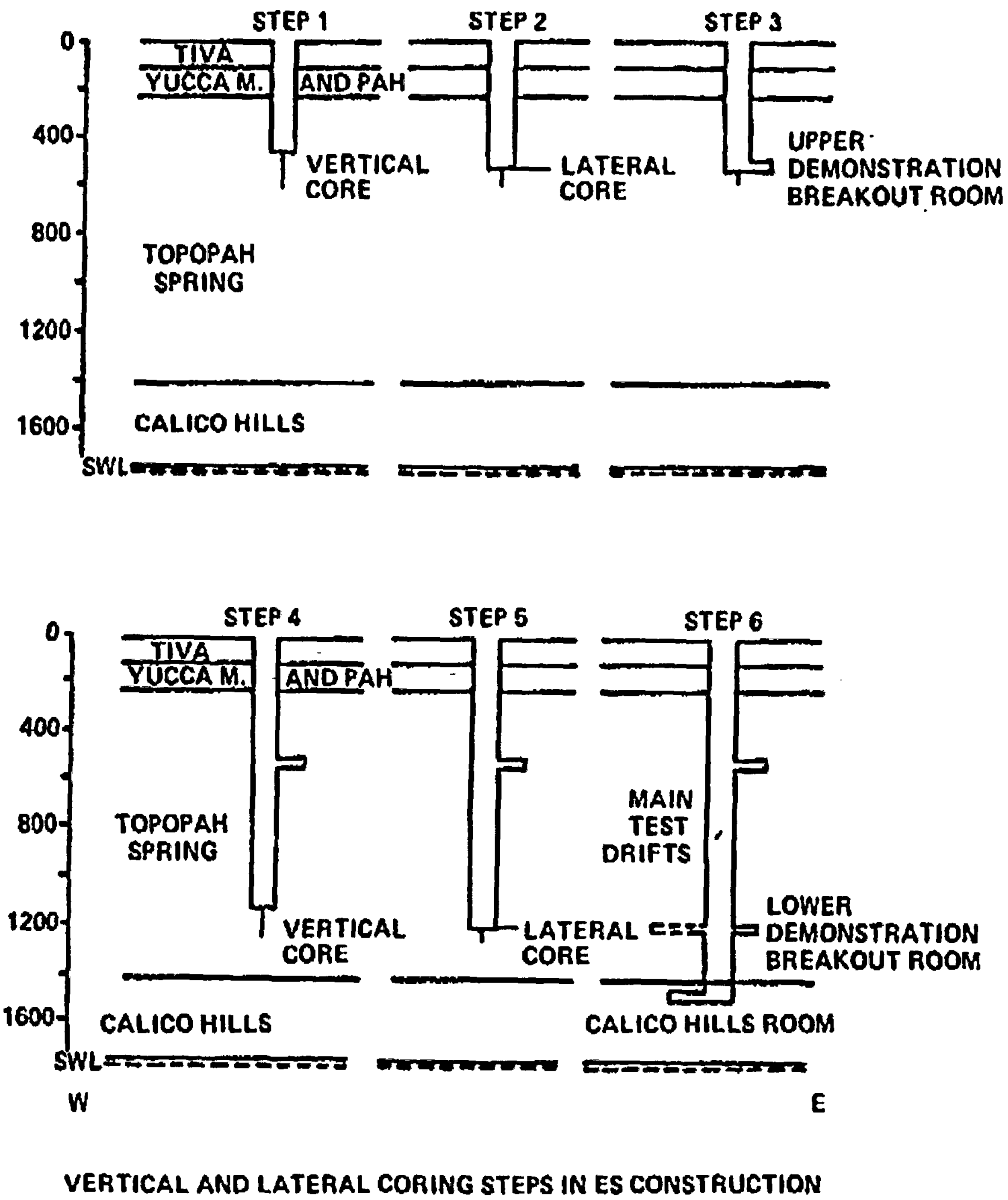


Figure 6-8. Main steps in ES-1 construction.

the shaft. No muck pocket will be constructed at the upper landing because the volume of rock mined there will be relatively small, ~840 m^3 (~29,570 ft^3). The landing area will be reinforced with rock bolts, wire mesh, steel sets, and lagging, grouted in place to ensure stability at the interface between the shaft, its liner, and the landing. Fractures and other features exposed in the walls and roof of the landing will be mapped during construction.

The upper DBR will probably be mined in a single pass to obtain the required dimensions of 18-m length, 6-m width, and 3.6-m height (60 by 20 by 12 ft). The excavation will be accomplished by drilling rounds of small-diameter shot holes about 2 m (7 ft) into the face, loading them with explosives, and blasting. The drill-hole patterns, explosive loads, and detonation timing will be designed to optimize blasting results. Following each blasting round, the drift will be ventilated to remove smoke, dust, and fumes before the miners reenter the drift to muck out the rubble. The muck will be transported to the shaft and loaded directly into the muck bucket for removal to the surface. Once the newly excavated drift space is cleaned out and made safe for entry, the scientists will map the fresh surface exposures.

Principal tests planned for the upper DBR include evaluations of mining and drilling techniques, rock-bolting techniques, measurement of rock-mass forces and deformation using rock-bolt load cells, multiple-point borehole extensometers (MPBXs), and drift convergence anchors. Some of these tests will begin concurrently with upper DBR mining so initial responses of the rock mass can be measured. Instrumentation used for the upper DBR tests will be wired into the Integrated Data System (see Sec. 6.0 in Part II). Data collection and analysis can therefore begin immediately and will continue while the shaft is mined to the lower DBR.

Other rock mechanics tests are also planned for the upper DBR after construction of the entire ESF is completed. They include rock-loading and strength tests and a small heater experiment. All of the tests planned for the upper DBR are described in detail in Sec. 3 in Part II.

6.2.5 Upper DBR to Lower DBR in ES-1

After instrumentation is installed and data acquisition is under way at the upper DBR, the shaft sinking will resume following the same construction and testing sequence as described above. Shaft-sinking operations will halt at the 80-, 200-, and 320-m (262-, 656-, and 1050-ft) depths between the upper and lower DBR, and measurements will be made on diametrical convergence using rod extensometers, rock-mass deformation behind the shaft wall using MPBXs, in situ stress by overcoring, and shaft-liner stress measurements using hydraulic pressure cells installed in the shaft liner. Follow-up data from the MPBXs and pressure cells will be acquired periodically thereafter.

At about 350 m (1150 ft), or about 15 m (50 ft) above the level of the lower DBR, a 30-m (100-ft) vertical hole will be air cored from the shaft bottom and the core examined to tentatively select the depth for the lower DBR (Fig. 6-8, Step 4). The same exploration and decision process as for the upper breakout level will be followed. The shaft will then be sunk incorporating a hitch and reinforced brow liner interval to the selected depth for the lower DBR, and lateral core holes will be drilled (Fig. 6-8, Step 5) to confirm that geologic and hydrologic conditions are suitable. An additional feature at this breakout level will be the construction of a 9-m- (30-ft-) deep muck pocket. Muck pocket construction will consist of excavating and installing a muck-holding pocket and chute adjacent to, but outside, the shaft diameter. The muck chute will discharge directly into the skip in the shaft (Fig. 6-7). The shaft will be deepened to about 387 m (1270 ft) so internal steel and skip guides can be installed down to the discharge chute level about 375 m (1230 ft).

6.2.6 Construction of the Lower DBR

Although the main test facility will ultimately be constructed at the 366-m (1200-ft) level, the shaft-sinking subcontractor will probably perform only limited drift mining at this time. Only the landing, the muck pocket, about 30 m (100 ft) of drift to the east of the shaft — including the 18.3-m (60-ft) DBR plus an electrical substation alcove — and roughly 23 m (75 ft) of drift to the west of the shaft (Fig. 6-2) are presently planned to be completed before continuing with ES-1 construction to total depth. (An alternative mining sequence would be to mine the access drift over to the bottom of ES-2 before mining ES-1 to total depth. This alternative is attractive because it would shorten the overall ESF construction schedule; however, there is concern that the additional mining might adversely impact some of the hydrology and transport testing. At the time of this writing, no decision has been reached.)

The tests planned for the lower DBR are the same as those already described for the upper DBR, with the exception of a heater test that will be performed only in the upper DBR. The azimuthal orientation of the lower DBR will be determined by using both the measured rock stresses and dominant fracture patterns. Once the lower DBR tests are in place, instrumentation will be installed and wired into the Integrated Data System and data collection will continue while shaft sinking proceeds to total depth.

6.2.7 Lower DBR to Total Depth, ES-1

With completion of the lower breakout test installations, the miners will continue sinking the shaft to its total depth of about 451 m (1480 ft), excluding a 1.2-m- (4-ft-) deep sump. The shaft will penetrate about 23 m (75 ft) into the tuffaceous beds of Calico Hills, of which the lower 15 m (50 ft) will be in the pervasively zeolitized interior. Penetration into the Calico Hills by the ESF is thus minimized, but the zeolitic zone is accessible for in situ testing that is judged necessary. Within the nonwelded Calico Hills tuff, from about 435 m (1425 ft) to total depth, the shaft-liner thickness will be increased to a minimum of 46 cm (18 in.), thus requiring the excavated diameter to increase by 0.3 m from 4.3 to 4.6 m (from 14 to 15 ft). From 436 to 448 m (1430 to 1470 ft), a reinforced hitch and brow will be constructed using steel tendon rods and rock bolts in order to protect the bottom drill room and sump station. At the shaft bottom, a 4- by 4- by 4-ft sump pit will be excavated, and pumps installed for water removal. To the west of the shaft, a T-shaped drill room will be excavated, following confirmation core drilling, for conducting additional tests in the Calico Hills tuff. With the completion of the shaft bottom excavations, the shaft-sinking contractor will return to the 1200-ft level to complete construction of ES-2 and the ESF drifts.

6.2.8 Construction of ES-2

With completion of ES-1 (and possibly after completion of certain hydrology and transport testing from the bottom drill room), the mining subcontractor will mobilize at the 366-m (1200-ft) level to complete construction of the access drift to ES-2, construct ES-2 as described immediately below, and complete construction of all remaining drifts and alcoves on this level, as described in Sec. 6.2.9.

The access drift to the bottom of ES-2 will be mined using conventional drill-blast-muck methods described in Sec. 6.2.9, below. This drift will be one of the first to be completed after the subcontractor returns to the 366-m (1200-ft) level and will either be mined in parallel with the drilling of the pilot hole or shortly after it has been completed (Table 6-2).

The ES-2 shaft and collar will be constructed using a minimum-size concrete surface pad upon which the raise-boring machine will be installed (Fig. 6-9). The ES-2 pad will be constructed directly on bedrock, thereby eliminating the need for a collar bell-out as is planned for ES-1. A 0.3-m- (12-in.-) diameter pilot hole will be drilled to the 366-m (1200-ft) level and, after the access drift is completed, an ~2-m- (~7-ft-) diameter reamer bit will be attached to the bottom of the drill steel. The raise-boring machine will then pull the rotating reamer bit slowly upward along the alignment of the pilot hole. Broken rock cut by the bit, plus any water used for cooling the reamer, will fall downhole and be removed and transported to the surface via the ES-1 muck conveyance system.

Once up-reaming is completed, surveys will be run in the unlined shaft to assess its condition, and then the ES-2 liner will be installed. Next, the guides for the emergency mancage plus any other internal hardware will be installed. Then the remainder of the ES-2 concrete surface pad will be built and the ventilation fans installed. Finally, the headframe, hoist, and emergency mancage will be installed to complete ES-2.

6.2.9 <u>Drift Construction at the Main Test Level, 366 m (1200 ft)</u>

The exact sequence of the drift mining is still to be determined but will be based on a number of considerations such as the need for early access to the second shaft, length of time necessary to complete the tests, test equipment requirements, how soon the integrated data system alcove is needed, plus certain mining requirements related to safety, utility needs, and so forth. Current plans are to mine the drifts using conventional drill-blast-muck methods.

TABLE 6-2. CONSTRUCTION SEQUENCE FOR MINING ES-2[a]

Event No.	Activity	Duration (days)[b]
	ES-2 CONSTRUCTION	
1	Mobilize ES-2 contractor.	22
2	Install drill on ES-2 pad.	22
3	Drill ES-2 pilot hole.	44
4	Drift to ES-2 pilot hole.	10[c]
5	Mine room for ES-2 borehole.	10[c]
6	Attach ES-2 reamer.	5
7	Upream ES-2 and remove muck.	22
8	Install ES-2 liner.	32
9	Install ES-2 headframe and vent fan.	10
10	Install ES-2 internals.	10
11	Install ES-2 conveyance.	5
	COMPLETE DRIFT MINING	
1	Mine test pillar.	15
2	Construct IDS.	10
	TOTAL	197

[a] Changes in this sequence are probable as plans are updated.

[b] Assumes 1.5 m (5 ft) per day, 1 round/day (2 shifts), 5 days/week.

[c] Concurrent activity: not additive to total duration.

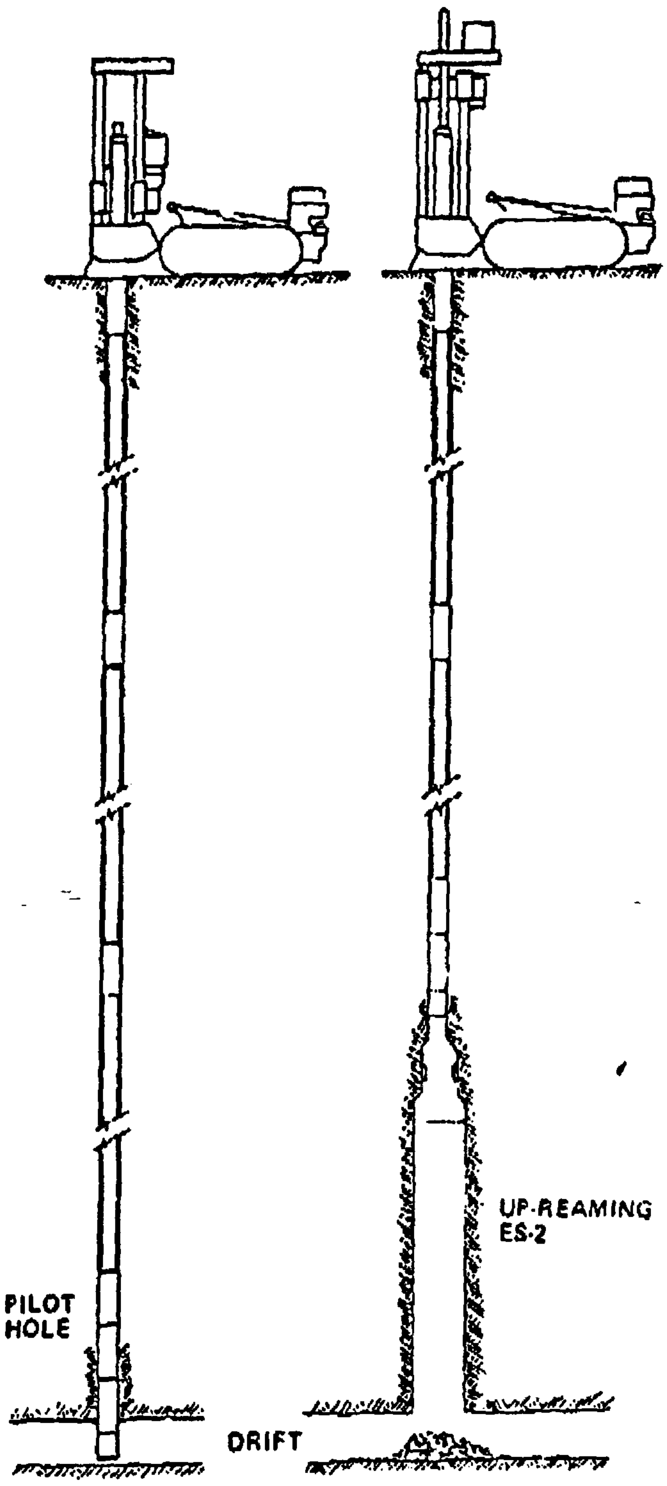


Figure 6-9. Raise boring with pilot hole drilled downward, followed by upreaming.

TABLE 6-3. CONSTRUCTION SEQUENCE FOR MINING THE 366-m (1200-ft) ESF LEVEL[a]

Event No.	Activity	Duration (weeks)[b]
1	Mine drift, lower DBR, and power alcove	During ES Construction (see table 6-1)
2	Drive drift 1-S	13
3	Drive ES-2 drift and excavate and support IDS drift	25
4	Mine room for ES-2 borehole	10
5	Drill and blast raise round	2[c]
6	Support raise round	1[c]
7	Attach ES-2 reamer	5[c]
8	Upream ES-2 borehole and remove muck	14[c]
9	Install vent door and permanent ventilation	2
10	Mine runaround drift and drift 1-N	30
11	Mine infiltration drift and bulk permeability drift	34
12	Mine drifts 1-W, 2-S, and3-S	41
13	Mine drift 2-W	48[d]
14	Mine drift 2-N	7
	TOTAL	210

[a] Changes in this sequence are probable as plans are updated.

[b] Assumes three shifts/day, 7 days/week

[c] Concurrent activity: not additive to total duration.

[d] Mining is part of mine-by test, thus may require more time than estimated.

The probable sequence for mining the main test facility drifts, alcoves, and test chambers is shown by the numbers in Fig. 6-10 and is listed in Table 6-3. The mining cycle for each drill, blast, and muck round is given below.

A. Blast Hole Drilling

1. Move drill jumbo to face.
2. Position drill.
3. Collar hole.
4. Drill hole approximately 2 m (7 ft) in length.

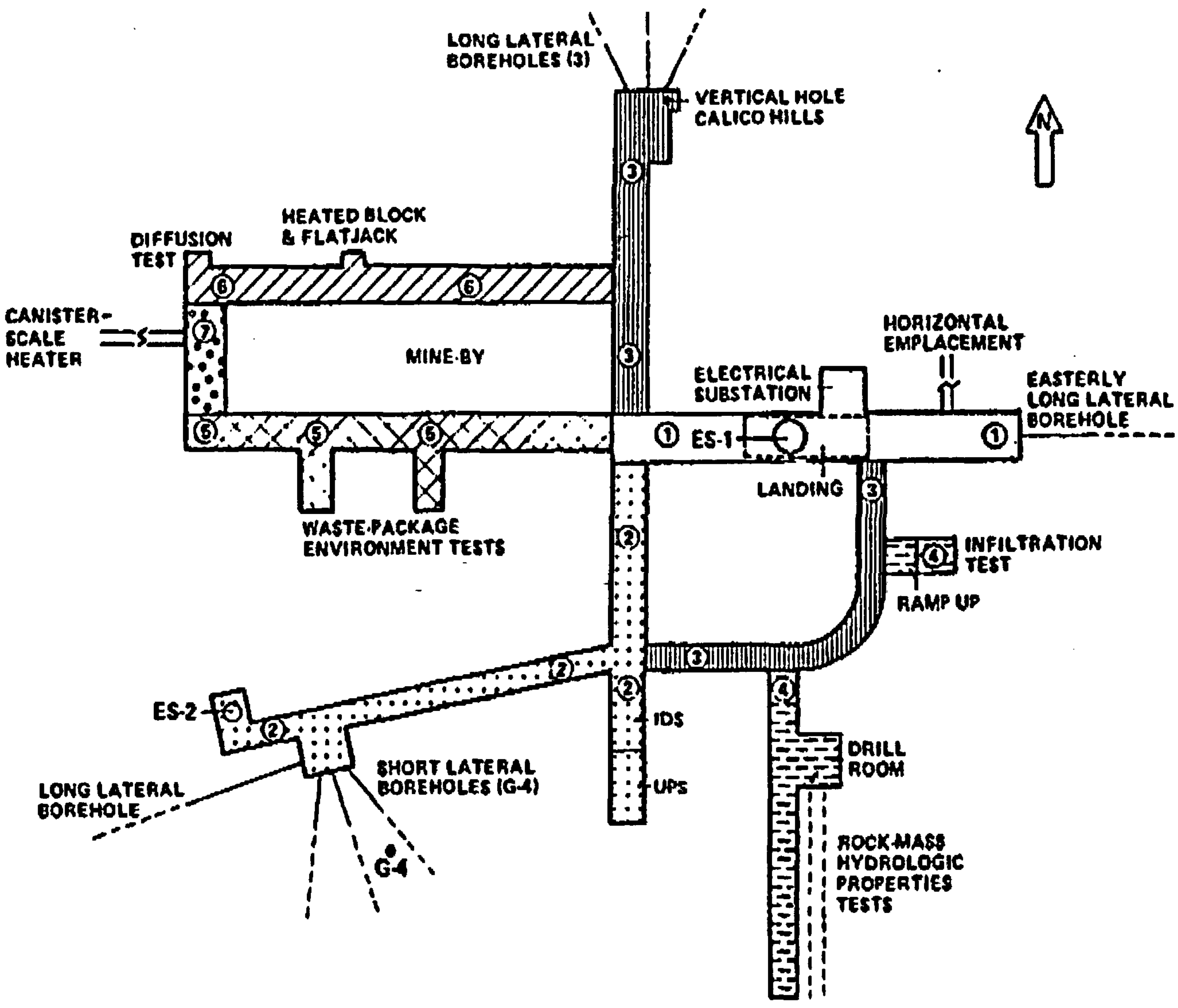


Figure 6-10. Sequence of ESF mining at the 366-m (1200-ft) level.

5. Withdraw bit from hole, simultaneously cleaning it out.
6. Reposition drill and repeat above operations until all blast holes are drilled.

B. Blasting Sequence
1. Load holes with explosives.
2. Install blasting caps and fusing.
3. Blast round.
4. Circulate air to remove smoke, fumes, and dust.

C. Mucking Out Sequence
1. Bar off any loose rock from back (roof) and walls.
2. Bring in load/haul/dump machine.
3. Load muck and haul to muck pocket/skip loader.
4. Repeat until all muck is removed.

D. Rock-Bolt Installation
1. Drill bolt holes — approximately 3 m (10 ft) long (location and spacing based on stability conditions).
2. Insert bolts.
3. Inject cement grout (or epoxy) and let set.
4. Install flat steel plate and torque down end nut. If needed, wire mesh would be attached to bolts and strung around drift opening.

As soon as conditions are deemed safe, the newly excavated drift walls will be mapped. This activity could occur before or after the rock bolts have been installed, depending on rock conditions. In drifts that are over 4 m (12 ft) in height, the mining will probably be in two stages, with an upper bench mined first and a lower bench second to achieve the total vertical dimension needed. If this is done, mapping will also be in two stages.

Once all of the mining has been completed, the subcontractor will demobilize his men and equipment and vacate the site. All subsequent construction operations to support ESF testing, including any needed mining and all drilling/coring, will then become the responsibility of REECo and the other Nevada Test Site support contractors.

6.3 Reference

MacDougall, H. R. (compiler), 1984. Two-Stage Repository Development at Yucca Mountain: An Engineering Feasibility Study, SAND84-1351, Sandia National Laboratories, Albuquerque, New Mexico.